METALLURGIA

THE BRITISH JOURNAL OF METALS

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METALLURGIA

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INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE "METALLURGICAL ENGINEER"

DECEMBER, 1953 Vol. XLVIII. No. 290

Training of Metallurgists

THE brilliance which William Thompson (later Lord Kelvin) displayed in his scientific work was, apparently, not so much in evidence in his teaching, and a delightful story is told of the occasion of his visit to London to be knighted. During his absence from the University, his lectures were taken by a junior member of the staff named Day. Now Day, although not in the same class as Thompson as a scientist, was a much better lecturer, and when the great man returned, he found written across the top of the blackboard: "Work while it is Day, for the (k)night cometh when no man can work."

We take this opportunity of extending to Readers our Cordial Greetings for the Festive Season and Good Wishes for the Coming Year

The competing claims of teaching ability and academic brilliance in the research field, as qualifications for lecturers in establishments for the training of metallurgists, were pressed at the Discussion on the Training of Metallurgists for Industry, organised by the Institute of Metals last month. Whilst it is generally agreed that a combination of the two would be ideal, it is recognised that insistence on such a dual qualification is impracticable. Which aspect, then, should be accounted the more important? Those on the side of research ability contend that the carrying out of research work gives a school that character, which, impressed on the general basic pattern, is responsible for its individuality, and helps to ensure that buoyancy of teaching which is considered by many to be essential. In technical colleges, too, the importance of the staff undertaking research work, particularly work closely linked with industry, has to be considered. The heavy demands of the time-table and the lack of incentive do not help, however, and it is felt that the awarding of external higher degrees by universities other than London would be a great stimulus to research of this kind. On the other hand, there are those who are not convinced that research ability is a prime requisite in a lecturer, and who hold the view that research projects are not a first essential in a teaching establishment.

As a metallurgist is something of a chemist, something of a physicist, and something of an engineer, and as he may be employed in such widely varying fields as fundamental research and technical sales, it is not surprising that there are differences of opinion as to what form his training should take. Twenty or thirty years ago, the course was largely descriptive, but considerable changes have resulted from a realisation of the need for a more thorough understanding of fundamental metallurgical principles, and the emphasis is now on "why," rather than "how." Such a training is believed to result in a graduate who, after brief industrial experience, is of more value to industry that the products of the older methods.

It appears that, for other reasons, industry and the graduate do not always see eye to eye on his value. There is at present an appreciable shortage of metallurgists, and it is felt in some quarters that the resultant competition for his services has tended to give the graduate a false sense of his importance. A humble approach to industry is recommended, it being emphasised that whether a man is a B.Sc. or a D.Sc. is soon forgotten in industry—he is judged solely by what he does. Commendable as a humility of approach may be, the danger of developing an inferiority complex must be guarded against, for this is incompatible with leadership and initiative. Graduates entering industry are expected to be possessed of new ideas and to have more than a usual amount of character and strength of purpose. Such qualifications do not make for graduates fitting into industry: they are essentially misfits, but, by their training and outlook, they should be capable of being blended into the existing structure without loss of character and initiative. These opposing views are in no way irreconcilable, and just as the newly qualified doctor "walks the wards," and the graduate engineer serves an "apprenticeship," so, too, should the metallurgist round off his academic training by acquiring industrial experience of a not too specialised kind after graduation. Schemes of training are operated by a number of firms, mainly in works of a metallurgical character, but there are also engineering firms who accept metallurgists into a course parallel with that for the engineering graduate, but with a metallurgical bias.

Reference has already been made to the shortage of metallurgists, and one of the matters giving cause for concern at the present time is the lack of recruits to the profession. The laws of supply and demand operate in the matter of labour as they do for commodities, and if industry wants metallurgists it must make the profession sufficiently attractive. This is not the main factor governing recruitment, however: little progress will be made in the matter so long as so many potential recruits leave school without even hearing of the subject. It is most important that the possibilities of careers in metallurgy should be made known to possible entrants through the scientific teaching staffs in the schools. Other possible recruits are those graduating in chemistry, physics and engineering who may be interested in entry at graduate level. The United Steel Companies this summer held two courses for senior schoolboys and undergraduates studying science subjects, to enable them to see for themselves the possibilities of a career in the steel industry. It is not very encouraging to learn, however, that a similar course for schoolmasters could not be held because of lack of support. This link between industry and recruits must be strengthened.

January Diary

4th

East Midlands Metallurgical Society. "The Contribution of Research to the Technology of Cast Iron," by Dr. R. V. Riley. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of British Foundrymen—Sheffield Branch. "Examples of Loam Moulding as Applied to Production of Pump Casings and Impellers," by E. Clipson. Sheffield College of Commerce and Technology, Dept. of Engineering, Pond Street, Sheffield, 1. 7.30 p.m.

5th

Institute of Metals—Oxford Local Section. "Industrial Methods of Electroplating," by Dr. G. E. Gardam. Oak Room, Cadena Café, Cornmarket Street, Oxford. 7 p.m.

Institution of Engineering Inspection—Coventry Branch. "Production and Fabrication of Aluminium," by a speaker from Northern Aluminium Co., Ltd. Room A5, Coventry Technical College. 7.30 p.m.

Institution of Engineering Inspection—South-Western Branch. "Radioactive Isotopes and their Uses," by R. S. Sharpe. Grand Hotel, Broad Street, Bristol. 7.30 p.m.

6th

Institute of British Foundrymen—Burnley Section. "Shell Moulding," by D. N. Buttrey. Municipal College, Ormerod Road, Burnley. 7.30 p.m.

Institute of Metals. Informal Discussion on "Lubricants for Metal-Working Operations in the Non-Ferrous Metal Industries." Birmingham University, Edgbaston, Birmingham, 15. 10.30 a.m.

Manchester Metallurgical Society. "Recent Developments in Magnetic Materials," by A. E. De Barr. Lecture Room, The Central Library, Manchester. 6.30 p.m.

7th

Institute of British Foundrymen—Lincolnshire Branch. "Aluminium Pattern Equipment by the Pressure Cast Plaster Process," by D. H. Potts. Lincoln Technical College, Lincoln. 7.15 p.m.

Institute of Metals—London Local Section. "The Rogerstone Strip Mill," by F. King. 4, Grosvenor Gardens, London, S.W.1. 6.30 p.m.

Institution of Engineering Inspection. "The Work of the Aluminium Development Association," by Dr. E. G. West. Royal Society of Arts, John Adam Street, Adelphi, London, W.C.1. 6 p.m.

Leeds Metallurgical Society. "Applications of Spheroidal Graphite Cast Iron," by Dr. A. B. Everest. Chemistry Department, The University, Leeds, 2. 7.15 p.m.

9th

Institute of British Foundrymen—Newcastle Branch. "Residual Stresses in Castings," by Dr. R. N. Parkins. Neville Hall, Westgate Road, Newcastle-upon-Tyne. 6 p.m.

Institute of British Foundrymen—Scottish Branch. "Core Assembly as a Production Aid to the Jobbing Foundry," by E. H. Beech and J. Hoyes. Royal Technical College, George Street, Glasgow. 3 p.m.

Institute of British Foundrymen—West Riding of Yorkshire Branch. "Aluminium Casting Alloys," by R. Mercer. Technical College, Bradford. 6.30 p.m.

11th

Institution of Production Engineers—Sheffield Section. "Extrusion of Metals," by J. T. Lewis, Grand Hotel, Sheffield. 6.30 p.m.

12th

Institute of Fuel. Joint Meeting with the Coke Oven Managers' Association (Southern Section). "New Carbonization Processes under Development and their Relation to Established Practice," by D. T. Barritt and T. Kennaway. Waldorf Hotel, Aldwych, London, W.C.2. 5.30 p.m.

Institute of Metals—South Wales Local Section. "Continuous Casting," by J. Crowther. University College, Metallurgy Department, Singleton Park, Swansea. 6.45 p.m.

North-East Metallurgical Society. Metallurgical Brains Trust. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

Sheffield Metallurgical Association. "Silicon Carbide Refractories," by G. Brooks. B.I.S.R.A., Hoyle Street, Sheffield. 7.30 p.m.

13th

Institute of British Foundrymen—Lancashire Branch. "The Running and Feeding of Castings," by R. W. Ruddle. Engineers' Club, Albert Square, Manchester. 7 p.m.

14th

Institute of British Foundrymen—Birmingham and West Midlands (Students' Section). Film Show, Grand Hotel, Birmingham. 7.15 p.m.

Liverpool Metallurgical Society. Discussion on "The Corrosion and Preservation of Metals." Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

15th

Institution of Mechanical Engineers. Thomas Lowe Gray Lecture: "High Temperature Steam and Gas Turbine Machinery for Marine Propulsion," by Dr. T. W. F. Brown. Storey's Gate, St. James's Park, London, S.W.1. 5.30 p.m.

North-East Coast Institution of Engineers and Shipbuilders. "Metallurgical Aspects of High Temperature Steam and Gas Turbine Plants," by Dr. J. M. Robertson. Mining Institute, Newcastle-upon-Tyne. 6.15 p.m.

18th

Sheffield Society of Engineers and Metallurgists. Presidential Address, by R. E. S. Fisher, M.C., University Building, St. George's Square Sheffield. 7.30 p.m.

19th

Incorporated Plant Engineers—Kent Branch. "Corrosion." Feed Water Specialist, Ltd., Liverpool. Bull Hotel, Rochester. 7 p.m.

Institute of British Foundrymen—East Anglian Section. "Metallising in Relation to Foundry Practice," by J. Barrington Stiles. Central Hall, Public Library, Ipswich. 7.30 p.m.

Institute of British Foundrymen—Slough Section. "Centrifugal Castings," by M. M. Hallett. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Sheffield Metallurgical Association. Résumé of Papers presented at the 6th Chemists' Conference (Ashorne Hill), 1953. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

20th

Institute of Fuel. "Hot-blast Cupola Practice," by W. J. Driscoll. The University, Leeds. 6.30 p.m.

Manchester Metallurgical Society. "Equilibrium Diagrams," by Prof. G. V. Raynor. Lecture Room, The Central Library, Manchester. 6.30 p.m.

Society of Chemical Industry—Corrosion Group. "Metallurgical Aspects of Dry Corrosion," by Dr. L. B. Pfeil, O.B.E., F.R.S. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

Society of Instrument Technology—South Yorkshire Section. "Temperature Measurement at the N.P.L.," by J. Hall. University Buildings, St. George's Square, Sheffield, 1. 7 p.m.

21st

Institute of Metals—Birmingham Local Section. "The Philosophy of Science," by Prof. S. Toulmin. Imperial Hotel, Temple Street, Birmingham. 6.30 p.m.

Society of Chemical Industry—Corrosion Group. Exhibition and Conversazione. Battersea Polytechnic, Battersea Park Road, London, S.W.11. 6.30 p.m.

22nd

North-East Metallurgical Society. "Evolution in Extraction Metallurgy," by Prof. C. W. Dannatt. King's College, Newcastle-upon-Tyne. 7.15 p.m.

23rd

Institute of British Foundrymen—Bristol and West of England Branch. "Pattern Making," by S. A. Horton. Westinghouse Brake & Signal Company, Ltd., Chippenham, 3 p.m.

Institute of British Foundrymen—East Midlands Branch. "Investigations on Dust Problems in Foundries," by E. Morgan and P. J. Moseley. Gas Showrooms, Nottingham. 6 p.m.

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B.I.S.R.A.'s New Sheffield Laboratories

Accommodation for Steelmaking, Metal Working and Metallurgy Divisions

The main building and metal working shop.

THE British iron and steel industry is at present engaged on the largest development programme in its history, costing many millions of pounds, and because the future value of this huge investment will depend, among other things, on full advantage being taken of the most up-to-date technical and scientific knowledge, the industry has been adding extensively to its research facilities. As an indication of this, the total staff engaged in the research departments of the principal steelmakers has almost trebled since the war, and to these must be added the staff of the British Iron and Steel Research Association, which numbers about 450.

Although the Association only came into existence in 1945, and is thus one of the younger metallurgical research associations, co-operative research activities in the iron and steel industry go back nearly 40 years. B.I.S.R.A.'s task on its formation was to gather together various research projects which were being collectively sponsored by the industry, and to extend the work to other fields. The work of the Association is carried on by five separate divisions, each responsible for its own section of the industry. The laboratory work of the divisions is placed in those parts of the country where particular branches of the industry can best be served. There is an ironmaking laboratory on the North East Coast at Middlesbrough and a laboratory at Swansea devoted to research on tinplate and other types of coating on steel. Plant engineering research is carried out in a groups of laboratories at Battersea, London, where fundamental work in physics and chemistry is also done. Fundamental work in ironmaking and ore treatment is carried out in a laboratory at Imperial College, London. Sheffield was chosen as an appropriate centre for the Association's work on the making, working and metallurgy of steel. These decentralised research centres make it possible for the scientific staff of B.I.S.R.A. not only to work in close contact with the industrial laboratories, but to work side by side with production staff, installing and testing new apparatus in steelworks and developing new processes.

B.I.S.R.A. has been carrying on research work in Sheffield for a number of years, thanks to facilities placed at its disposal by such organisations as the University of Sheffield and the Admiralty Bragg Laboratory. Now, however, it has its own laboratories at Hoyle Street, and an important step forward in the Association's progress was marked by their official opening by H.R.H. The Duke of Edinburgh on November 19th.

The new laboratories house the greater part of the Association's laboratory facilities for steelmaking, mechanical working and metallurgy. The main interests of the workers in these three fields are, respectively: the open hearth and electric furnace steelmaking processes, and the casting of ingots; the processes from the ingot to the finished wrought product—plate sheet, sections, wire and forgings; and the behaviour of steel, under heat treatment, for example, and special steels.

Each division has at its disposal the special equipment required for its own research programme, but duplication is avoided by joint use of general research facilities, and the provision of common services through a central administrative and engineering section. This arrangement has the additional advantage that the heads of the three laboratories are relieved of almost all administration, other than day-to-day direction of their respective research programmes A local group manager, responsible for all the central services, varying from clerical and accountancy to engineering and maintenance, takes the bulk of the administrative work and co-ordinates the needs of the three laboratories.

In addition to the three separate laboratories, accommodation has been provided, on a repayment basis, for a young but energetic section under the Cutlery Research Council. This section is completely independent of B.I.S.R.A., but has available all the central administrative services and thereby is saved the heavy overhead costs of these. In addition, there is a full exchange of technical knowledge with the three other laboratories; in other words, the Cutlery Section works in a good and extensive research atmosphere. This arrangement may well prove to be a prototype of a solution to the problem of the small research association.

The 10-cwt. electric arc melting furnace.

General view of the metal working shop showing the rolling mill, forging press and wire drawing machine.

It is a particular feature of the laboratories that, in addition to the usual mixture of research rooms and offices, there are two so-called " plant laboratories " in which experiments not far removed from the scale of steelworks' operation can be carried out. They contain, in particular, an electric arc furnace, a rolling mill, a forging press and a wire drawing machine, each basically conventional in design, but incorporating certain special features which make them suitable for research and which, incidentally, may point the way to future developments.

Since its inception in 1945, B.I.S.R.A. has held to the policy that its function was not merely to do research, but to ensure that it is vigorously followed through to the stage of application. Some notable successes have been achieved and reported, for example, in sintering ore fines, in the design and instrumentation of open hearth furnaces, and in the development of rolling mill instruments, but the great gap in scale between laboratory experiments and iron and steel works practice is an enduring difficulty in this branch of industrial research. The provision of intermediate scale plant at the laboratories, in close proximity to the industrial plant of the most famous steelmaking district in the world, is another stepping stone across the gap between science and industry, and is seen as an integral part of the iron and steel industry's great post-war development plans.

The Buildings

The laboratories consist of four new and three older buildings. The three new laboratories are : main block (three storeys totalling approximately 30,000 sq. ft. floor area), the metal working shop (10,000 sq. ft.), the melting shop (4,000 sq. ft.). The other buildings are the cutlery laboratory (formerly the offices of Daniel Doncaster and Sons, Ltd.), the machine shop, the furnace model room and the annexe (a temporary building erected in 1948).

The main block contains laboratories and work rooms, administrative offices, a conference room, a library and a canteen. It is so built that it can be extended at either end with the minimum cost and disturbance to current use, while the steel work and foundations are such as to allow the addition of another storey to the building. All internal walls and partitions can be easily removed and new layouts built up.

The principal services, electricity, gas, heating and air conditioning, water and drainage, are laid in a comprehensive and everywhere accessible system of ducts which is carried to every working room in the building. This system allows work rooms and offices to be converted into laboratories, and vice-versa, without interfering with the structure of the building.

Four vertical brick-built shafts rise from main ducts below the basement, and pass up through each floor to the roof. On each floor there are large access doors opening from the corridor walls into the vertical ducts; adjoining each duct is a recess in the corridor wall housing fire equipment below and electrical distribution boxes above.

Each corridor has a false ceiling which forms a horizontal duct running its full length and width. Into these the services are led from the vertical ducts. Access is obtained via removable ceiling panels. Secondary ducts branch off at right angles to the corridor beneath the floors of the adjacent rooms, and are accessible through removable panels in the ceilings of the rooms below. From these, tertiary ducts branch off parallel to the corridors to complete the pattern of distribution. These are accessible via removable covers set in the floors, and through which the services are led into the rooms.

A particularly interesting feature of this system is that the loss of floor space due to the ducting is less than one per cent. of the whole, while the utilisation of wall space in the laboratories is entirely unaffected.

The new laboratories were begun in August, 1950. Messrs. Husband and Company have acted as consulting engineers and architects ; George Longden & Co., Ltd.

have been the chief contractors. The cost has been of the order of £300,000 for the buildings and £200,000 for the equipment.

It is interesting to note that the works of Daniel Doncaster & Sons, Ltd., included three cementation furnaces, interesting examples of a centuries-old, now extinct, process for making blister steel. The last of these furnaces was drawn in 1951, and it is believed to have been the last in the world to operate. The last survivor of one of the oldest methods of steelmaking known has made way for a research station which is, in many respects, the most modern in the world.

The Melting Shop

The melting shop consists of a single-storey steel-framed main shop and a two-storey brick building adjoining. The design allows for future extension in length. The floor of the main shop is of concrete and contains no service ducts : laboratory services enter the building from a service duct immediately outside the wall, and they pass in the form of ring mains at high and low level round the main shop interior walls. The ground floor of the adjoining building houses the station compressed air plant and the arc furnace transformer and its associated switchgear and controls. The first floor houses a small laboratory and an emergency water tank which is part of the water system to the arc furnace.

The Arc Furnace

The principal item of equipment in the melting shop is the 10 cwt. arc furnace. Supplied by the Electric Furnace Co., Ltd., it is in many ways of conventional Heroult design, but it incorporates a number of special features which widen the range over which research can be conducted. The shell is 5 ft. in dia., and the height of the walls can be varied from 1 ft. 5 in. to 2 ft. 2 in. (sill to roof ring) by the inclusion of separate sections 3 in. and 6 in. in depth. At present, only the maximum and minimum heights are being used, and these two sections have been bolted together and a flange added on the inside, so that the combined 9 in. section, complete with its brickwork, can readily be inserted or removed. Graphite electrodes, 4 in. in dia., are in use at present, on a 12 in. dia. pitch circle, and provision has been made for the variation of the pitch circle up to the full diameter of the bath, and for the use of 7 in. dia. electrodes as an alternative. Research will also be done on Soderberg electrodes and on other alternatives to graphite. The electrode controllers are of the Rotadyne type. Silica brick has normally been used in the roof and chrome magnesite for the walls so far ; for special purposes a firebrick roof is to be used. The furnace bottom is of austenitic steel in order that induction stirring equipment can be fitted at a later date, if required. A specially high maximum forward tilt of 60° is provided, with 15° reverse tilt.

The furnace transformer, supplied by the Metropolitan-Vickers Electrical Co., Ltd., is of 500 kVA nominal capacity, and is larger than would normally be used on a 10 cwt. furnace, in order that the effects of high-power input rates can be investigated. It has eight voltage tappings ranging from 64 to 180 V. The melting shop is served by a 3-ton ground-controlled overhead travelling crane, supplied by Herbert Morris, Ltd.

The steelmelting plant is being used in attempts to widen the range of steels that can be made economically in electric furnaces, with consequent advantages in quality. Many types of steel, for example low carbon rimming steels, are border-line cases. So close are these steels to the border that quite small economies in electric furnace operation would bring them over.

The work so far carried out with the furnace has been mainly concerned with the effects of a number of variables on power and electrode consumption. This type of work aims at reducing operating costs, and thus widening the range of steels over which the arc furnace can compete with the open hearth. The biggest effect so far found is, naturally, that of rate of power input during melting down on power consumed during this period, and in the B.I.S.R.A. furnace about 20% less power is required with an input rate of 500 kVA than with 250 kVA. This underlines the importance of adequate transformer capacity.

Successes have already been achieved in work on electrode consumption, and this offers one of the major fields for economy. Further small scale experiments on protective coatings for electrodes have also given promising results. Work on refractory wear is now also in progress. Other types of work envisaged are on steel quality and the chemistry of the steelmaking process. A further important purpose of the furnace is to provide molten steel for a variety of experiments, mainly on problems in casting.

The Metal Working Shop

The metal working shop houses a strip rolling mill, a wire drawing machine and a forging press, all of industrial size, as well as various smaller pieces of equipment. It is a single storey building of steel portal frame construction, with brick walls and a concrete floor. Large hollow glass-brick panels are inserted between most of the portal frames, in order to obtain good natural lighting combined with low heat losses.

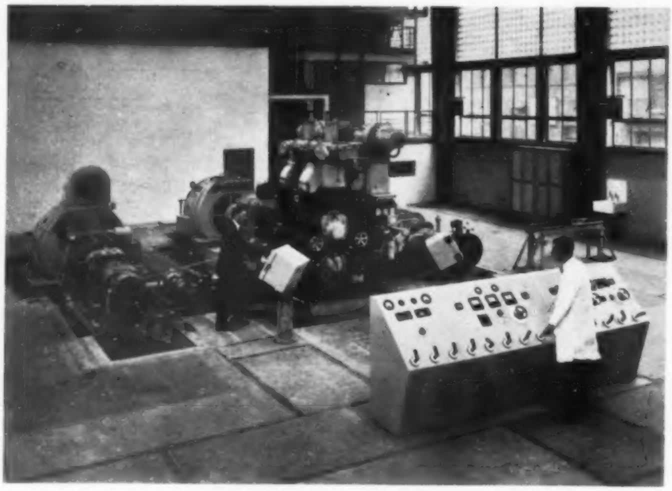
The floor of the building incorporates a network of trenches or ducts for the housing of laboratory services. Two of these ducts run the whole length of the building, immediately inside the walls, and are connected together by two further limbs running across the width of the shop. These four main ducts have removable concrete slab covers, and are connected with the duct network extensions to the other two buildings. They are provided with built-in lighting, and can be entered from the electrical sub-station, the longitudinal ones being large enough for maintenance men to walk through them. There are also numerous smaller ducts branching from the main limbs.

There is a 10-ton E.O.T. crane, whose cab design incorporates parts of the B.I.S.R.A. steelworks crane specification, and which is used for hoisting steel coils from storage in the main block basement, and lifting the sub-station transformers when required. An interesting feature is that the mill motor generator set is cooled by forcing cold air from a small pressurised basement through holes in its foundation and into the machines. The warmed air then exhausts into the motor generator room and escapes into the main duct system, thus combating dampness in the tunnels.

Although the main block adjoins the metal working shop, its foundations and structure are completely separate, so as to minimise the transmission of vibration from the heavy plant in the metal working shop.

The Rolling Mill

The rolling mill was designed and built by W. H. A. Robertson & Co., Ltd., who sub-contracted the electrical



The rolling mill and control console.

design and construction to the Metropolitan-Vickers Electrical Co., Ltd., and the cable installation to W. J. Furse & Co. (Manchester), Ltd. It is a high-speed reversible four-high cold strip mill and will accommodate work rolls from 3⅛ in. to 7 in. dia. The back-up rolls are 14½ in. dia., and all rolls have a 14 in. face width. Roll balance and coil ejection is hydraulic, and the wiper and guide table movements are pneumatic. Screw-down is by two 5 h.p. motors, operated independently or together, the total design load being 300 tons. The main mill motor has a maximum continuous output of 750 h.p., and each coiler is equipped with a 200 h.p. motor which enables a wide range of front and back tensions to be applied. The coiler drums will take a 4 ton, 56 in. dia., 12 in. wide coil. Provision is made to convert the mill into a two-high machine with 14½ in. dia. rolls if required in the future.

In order to allow as wide a field of cold rolling research as possible to be undertaken, operating conditions have been extended far beyond the normal production limits. The speed of the main motor can be varied from zero to 955 r.p.m., giving an ingoing strip speed of 10 to 1,750 ft./min. with 7 in. dia. rolls. Any given speed can be preset and repeated accurately within these limits, irrespective of load. The acceleration from zero to maximum speed can be pre-set between 10 and 30 seconds. Back and front tensions can be applied, and for a given setting are kept constant during acceleration, deceleration and change in coil diameter. Under normal running conditions, the maximum tension available is 2 tons per side, but there is a control which will increase this by any factor up to 100%. Under stalled conditions, the tension is automatically reduced, but by pressing a button the running tension can be obtained for short periods. It is also possible to reel strip from one coiler to the other under full tension control with the rolls lifted.

The coiler motors are each fed from their own generator, and controlled by Metadynes. Apart from controlling tensions under the conditions mentioned, the Metadynes provide for draught adjustment up to 90%; inching each coiler independently or with the mill; adjusting speeds when different diameter work rolls are fitted; and also prevent the motors overspeeding if the strip breaks. At speeds below 200 ft./min. the mill is controlled from a separate Metadyne system which obtains a signal from a belt-driven tachogenerator on the mill motor extension shaft.

The control desk is divided into three sections. To the operator's right side there are the coiler motor and tension controls. On the left are screwdown controls, and grouped in the middle are the master switch and subsidiary running controls. For normal running, the pre-set speed control handwheel is set to the required value, the acceleration rate set as required, and the mill started and controlled by the master switch.

The roll-force, back and front tensions, and strip gauge are measured by means of instruments designed and built in the B.I.S.R.A. Laboratories and displayed on the mill housing in front of the operator. Repeater meters are mounted in a cabinet so that a continuous photographic record can be obtained if required. The mill is also equipped for research on several systems of automatic gauge control.

The mill, which is probably one of the most fully instrumented in the world, is being used for trials of various methods of gauge control of cold rolled strip. One method developed by B.I.S.R.A. during the last few years has already operated successfully for some months in the works of a member firm. The importance of gauge control is shown by the fact that with the methods normally in use at present, 8 or 10% of the strip made in a modern high speed mill may be off gauge.

The Forging Press

The press was originally built in 1939 by the Hydraulic Engineering Co., Ltd., and was supplied to B.I.S.R.A. by George Cohen, Sons & Co., Ltd. in 1952 after being stripped, completely overhauled, and rebuilt. It is a vertical down-stroke hydraulic machine of 200 tons capacity, the load being applied by a double-acting piston-type ram 10 in. by 10¾ in. dia. with a stroke of 15 in. The moving table is guided by four 6 in. dia. steel columns, and is fitted with removable phosphor bronze bushes. The working tables measure 25 in. by 31 in., and are provided with platens which have female cruciform spigots for locating and locking the tools in position. The maximum daylight between platens is 26 in.

As the machine is used for general research into forging problems, it has to be capable of providing widely varying speeds and loads. The maximum load can be set anywhere between the limits 4–200 tons and repeated with an accuracy of ± 2½%. Within the range 0–100 tons load (equivalent to 0–2,500 lb./sq. in. oil pressure) the ram speed is infinitely variable between 0·03 in./sec. and 3·90 in./sec. Under heavier loading, the maximum ram speed is reduced, giving limits of 0·3 to 1·54 in./sec. Automatic pre-filling is provided to reduce the idle part of the stroke to a minimum, and a ram return speed of 2·85 in./sec. is obtained.

In order to provide for the wide range of speeds and pressures required, the new Towler "Electraulic" pumping and control gear is used. The pumping equipment consists of four high-speed units, each comprising two "in line" plunger-type pumps and a 25 h.p. driving motor, together with a smaller high-speed axial plunger pump driven by a 4 h.p. motor. Oil is used as

the pressure fluid in a completely closed circuit, the main storage tank being on top of the press. The five pump motors are controlled by a ten-way push-button station on the control panel, which provides a "stop" and "start" button for each individual motor. Next to this is a seven-way station giving "close," "open" and "stop" control on the ram, and "in" and "out" control on each of two solenoid operated by-pass valves. Also on the control panel is a pressure gauge, calibrated in lb./sq. in. oil pressure, and a knob controlling a metering valve which enables any desired part of the 2,000 cu. in./min. delivery of one pump to be by-passed to exhaust. On top of the cabinet is a calibrated thimble control for the variable-pressure relief and unloading valve.

To operate the press, the small pilot pump is first started, as a supply from this operates some of the system's valves. The pressing speed required is then obtained by starting a selected number of the main pumps and obtaining a fine adjustment by exhausting part of the output of one pump. The variable-pressure relief valve is set at the required pressure, then the press can be operated by the "close," "stop" and "open" buttons. When the ram is stopped, pressure is maintained in the cylinder by the pilot pump. Limiting switches are fitted to enable any stroke to be repeated simply by operating the "open" and "close" buttons.

The 200-ton forging press.

The Wire-Drawing Machine

The wire-drawing machine was designed and built by the Marshall Richards Machine Co., Ltd., to B.I.S.R.A. specification. It is a two-hole, straight-line machine, with a spool feed and take-up and with 18 in. dia. capstans mounted on vertical shafts coupled directly to the driving motors. Interchangeable drawing sleeves are provided for the capstans, allowing for the number of wire laps to be varied up to 3 in. in height, without affecting the straight lead out from the dies. Capstans and dies are water-cooled from a constant pressure supply obtained by passing mains water through a special reducing valve. It is possible to submerge the whole of the drawing compartment in lubricant, circulating it in a closed system, or to spray the capstans, dies, and wire, the temperature of the lubricant being thermostatically controlled. Alternatively, soap boxes may be fitted for dry drawing. The feed and take-up spools are motor driven, and can be either 36 in. or 42 in. dia., to carry approximately 1 ton or 2 tons of wire, respectively. The feed spool mechanism can be used at low speeds to make up spools from coils of wire, and a capstan can be substituted for the take-up spool for coiling.

The machine can be used to draw both ferrous and non-ferrous wire of an initial diameter between 0·040 in. and 0·104 in. under widely varying conditions. Drawing can be wet or dry, under temperatures ranging from approximately 10° C. to 130° C., with an area reduction per pass from 0 to 45%. Interpass and spool tensions can be varied from zero to the breaking point of the wire. It can also be run as a slip machine, in which case the capstan motors are linked by interchangeable pulleys and belts, or as a single holer with the first die removed and the first capstan acting as a brake. The maximum inlet speed is 2,500 ft./min. and in an emergency it is possible to stop the full feed spool from this speed in 2 seconds under a combination of dynamic braking, and twin electro-magnetic brakes. The maximum finishing speed is 5,000 ft./min.

The wire drawing machine.

In order to obtain the wide range of speed required, the D.C. motors driving the capstans and spools are supplied with current from a grid-controlled mercury arc rectifier, by means of which a continuous variation of armature voltage can be obtained, giving continuous speed variation. At high speed, control is by a rheostat in the motor field circuit. By this system of control, a constant torque is obtained from zero to a speed of approximately 3¼ r.p.m. per volt on the armature. The capstan motors are rated at 55 h.p. and the spool motors at 20 h.p., both at 1,000 r.p.m. A number of safety interlocks are provided in the drive, and the whole plant is automatically shut down if any motor over-speeds, or passes maximum voltage or current, or if the wire breaks. When

the cover of the drawing compartment is open, the machine can only be run at slow speed.

The main controls are on a desk facing the machine. These include start and stop controls for the whole of the plant, speed control of the entire plant, and acceleration and deceleration rate adjustments for capstan and spool torques. There is also a switch to allow the machine to operate without the lubricant system running. On the machine are controls for independent capstan inching, coarse adjustment of torque, speed control, and control of water and lubricant temperature and flow. A comprehensive range of instruments which gives full details of the machine's performance is mounted on a separate panel and can be recorded photographically.

This machine is one of the fastest for its size in the world but, although normal drawing speeds have increased enormously during the last few years, many types of steel wire must be drawn comparatively slowly for technical reasons connected with lubrication. This is one of the problems on which the machine is being used, and a technique has been devised for measuring the thickness of the film of lubricant on a wire while it is actually passing through the die. An oscilloscope trace indicates the film thickness (though it may be of the order of only one thousandth of a millimeter) throughout the speed range.

The Metallurgical Laboratories

Although the work of this section covers a very wide field, reference may be made to one or two of the investigations in progress. Of considerable importance in, amongst others, the motor car body industry, is the work which is going on to solve the problem of stretcher strains. These are markings, such as ripples and waves, which appear on the surface of certain steel sheets after pressing. The pressings manufacturer cannot be sure of avoiding this trouble unless he uses his sheets as soon as they come from the mills, where they are given what can be called an immunising treatment. This immunity wears off in a time which varies according to a number of circumstances.

Some of the work at these laboratories is directed to finding out the metallurgical reasons for stretcher strains, with long term cure and prevention in view. Other work has been directed at the shorter term problem of developing methods of determining for the pressings manufacturer how long the immunity given to his supplies of sheet will last, and to the similar problem of developing a test which will show for how long a treated sheet will remain immune. Such a test has now been developed. What has already resulted as a rather unexpected by-product of this research is a method of using X-rays to tell whether a sheet was originally subjected to immunising treatment at all. This test is now a reliable one, and has been used in industry. Not only will it tell whether a sheet has been immunised, but it will reveal some of the details of the treatment to which the sheet has been subjected.

Electrical transformer sheets provide another interesting subject for investigation, as the efficiency depends on the magnetic and electrical characteristics of the core materials. During the last 50 years electrical sheet has been so improved that transformers have virtually halved in size for a given output. Without this improvement, development of the comprehensive grid scheme would probably have been prohibitively expensive. So great has the improvement been, that further progress is even more arduous and difficult. In working on this important subject, therefore, the B.I.S.R.A. laboratories have to consider the effects of very small amounts of impurities—for example, 0·0001% of nitrogen. For this reason a high vacuum melting furnace has been installed, in which steel can be melted in conditions where the precise amounts of impurities can be controlled, and their effects gauged. This furnace will be described later.

The importance of rapid, accurate and reproducible methods of determining the composition of iron and steel and the raw materials of manufacture has led to a study of a number of chemical and physical techniques. In spectrographic analysis, an arc or spark is struck between a piece of the metal under examination and an electrode. The light from the arc or spar, is split up by a prism, and the spectrum so caused is examined and the presence of the elements composing the steel detected and measured. The method has been in use for several years, and has very marked advantages because of its speed, and the fact that very small samples can be used.

It could be much more widely useful, however, if one disadvantage were overcome. Because it is a comparatively new method, and has been built up very largely by individual works for operation in their own particular circumstances, it is not reproducible between various works. Two or more works or laboratories may get slightly different answers from similar specimens. Even the same works or laboratory may get slightly different answers from repeated attempts.

This lack of reproducibility is partly due to the use of different source units—that is the electrical methods used to excite the arc or spark : most laboratories have built their own units. B.I.S.R.A. is now experimenting with a new sort of unit which makes possible more complete control of the arc or spark, and which may lead the way to greater uniformity of practice throughout the industry, and a consequent widening of the usefulness of the new method.

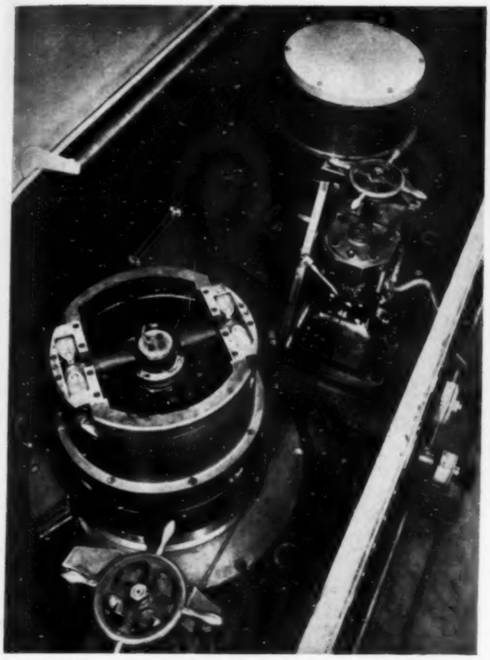
Although the equipment used by the Metallurgy Division is not built on such a large scale as that described earlier, reference may be made to a few items of special interest.

High-Vacuum Melting and Casting Set.

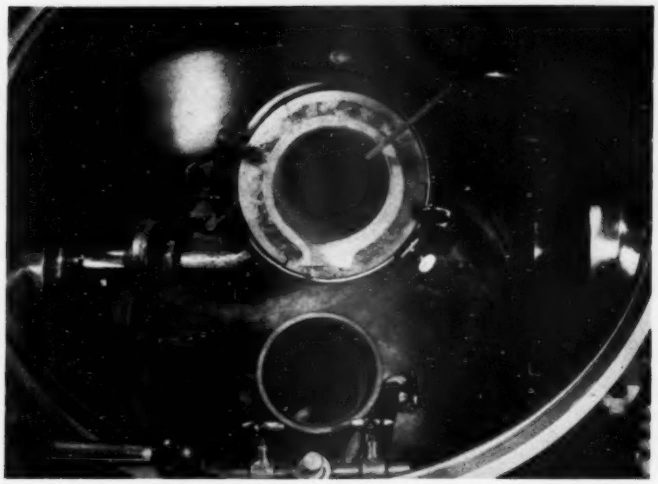
An induction, high-vacuum melting and casting equipment has been supplied by Geraetebau-Anstalt Balzers, of Liechtenstein, through the British agents, Allifor Trading Co., Ltd. It comprises a V.S.G.25 high-vacuum melting and casting set capable of dealing with 55 lb. of iron, and an open air furnace suitable for melting 100 lb. of iron. Both furnaces are induction heated and are fed from a common high-frequency (10,000c/s) vertical spindle A.E.G. motor generator of 110 kW. rating.

The special feature of the apparatus, i.e., the melting and casting within the vacuum, embodies a fixed, double-walled water-cooled container of stainless steel, volume 18½ cu. ft., with a rotatable coaxial high-frequency lead-through which forms a carrier for the induction coil. The hinged water-cooled lid seats on a rubber gasket, and is fitted with a quartz glass observation window and a large vacuum-tight storage chamber with six compartments for containing metals or alloys to be added during the course of the melt. If required, as much as 40 lb. of materials can be added to the melt within the high vacuum.

The high-vacuum pumping set includes a two-stage rotary backing pump, a three stage diffusion pump with



View of the wire drawing machine showing details of capstans and dies with in-built torque measurement on nearer capstan.



View of the interior of the vacuum induction melting furnace showing crucible, ingot mould and quick immersion thermocouple.

a baffle, a backing pump reservoir and a well-designed valve assembly unit. An additional gas inlet valve and an indicating pressure gauge is provided on the valve block so that the melting process can also be carried out in an inert gas atmosphere, if necessary under reduced pressure. The exhausting cross-section of the high-vacuum connection is nearly 10 in. dia., thus enabling low ultimate pressures to be obtained. Typical pumping times in the cold are from 180 to 0·1 mm. of mercury in 2·5 min., to 10^{-3} mm. mercury in 3 min., and to 3×10^{-5} mm. mercury in 30 min. With hot metal it is claimed that 10^{-4} mm. mercury can be obtained.

The electrical control gear for the pumping set is built on to the valve unit and above it is arranged the vacuum indicator with a selector switch for monitoring the vacuum in the container and in the backing reservoir. A spare position is available for monitoring at any other chosen point in the system.

Casting in high vacuum is accomplished by tilting the induction coil containing the melting crucible, and pouring the molten metal into a fixed mould supported on an adjustable stainless steel baseplate. Facilities are available for either heating or cooling the mould. A dip thermocouple is provided which can be operated by a handle outside the container.

The set is to be used for several purposes, including production of metals and alloys of the highest purity, free from gas; application of special casting processes; vacuum distillation of metals; vacuum sintering.

Vacuum Fusion Gas Analysis Apparatus.

An apparatus for the vacuum fusion analysis of gases in steel has been designed to overcome some of the limitations experienced by earlier users of this method. It is manufactured by W. Edwards & Co., Ltd.

A solid sample is introduced into a graphite crucible in an evacuated system at an elevated temperature of the order of 1,700° C. and at 10^{-6} mm. Hg. Under these conditions, the oxides are reduced by carbon to carbon monoxide, the nitrides dissociate, and hydrogen is also liberated. Heating of the crucible and specimen is carried out by high-frequency induction, using a Phillips high-frequency generator, type B13/1, having an output of 7 kW. at a frequency of 350 kc./s.

Since the reduction of oxides by carbon is an equilibrium type of reaction, it is necessary to remove the products of reaction rapidly to ensure completion of the reaction. For this purpose a high-speed mercury vapour diffusion pump is employed. If the efficiency of the pump is not to be impeded by the pressure of gases collecting on the backing side, it must be capable of operating against high backing pressures. The pump used is one manufactured by W. Edwards & Co., type 2M4. It is a four-stage pump capable of pumping at a rate of 75 litres/sec. against high backing pressures, with only moderate heater input. Limiting backing pressure is 35 mm. Hg. and heater capacity 850 W. The gases are collected in a Toepler pump, whence they are transferred to a suitable gas analysis apparatus. The dead space to Toepler pump ratio is greater than 10 : 1. The complete unit is robust, self-contained and extremely mobile, having a wide metal header, and allowing full advantage to be taken of the pumping speed.

The specimen is introduced through a greaseless vacuum lock on the left of the metal header. Thus it is introduced into a readily pumped vacuum system and not stored under vacuum conditions for lengthy periods before analysis. Pyrometer readings can be taken through an optically polished disc in the top of the metal header; a metal protection for the disc is operated from outside the system, as is the ball stopper for the crucible. In accordance with Sloman's recommendation in the third report of the Oxygen Sub-Committee of the Committee on the Heterogenity of Steel Ingots, May, 1941, grease joints have been eliminated from the system.

Fatigue Testing Machines.

Twelve fatigue testing machines of the two-point loading rotating bending type, similar in design to those used by M.E.R.O. and the National Physical Laboratory,

have been installed. Loading is achieved by means of a couple acting through a rigid link system, producing what is virtually a condition of constant bending moment over the whole of the test length of the specimen. The speed of the machines is controlled, and rates up to 5,000 r.p.m. are possible, at which speed the machines are clear of any resonance which might influence the results. Each of the 12 machines is, therefore, able to provide approximately 7,000,000 stress cycles every 24 hours.

Correspondence

Hot Dip Aluminising

The Editor, METALLURGIA.
Sir,

I have read with great interest the paper by M. L. Hughes and D. P. Moses in your September issue on the work carried out so far at the British Iron and Steel Research Association's Laboratories on the hot-dip aluminising of steel. It is pointed out in the paper that, while aluminium offers markedly better resistance to the environments which are most harmful to zinc, it is decidedly less effective in giving sacrificial protection to any exposed steel. It is not clear from the paper to what extent the latter experience has been accentuated by pre-coats of copper (which would tend to counteract any sacrificial protection offered by the top coat), but the potential difference between aluminium and steel is relatively small. The remedy may, therefore, lie in the use of an aluminium-zinc alloy.

The potentials assumed by aluminium and zinc and their alloys when immersed in simple salt solutions, such as 3% sodium chloride, show that the addition of 1% zinc to aluminium brings the potential midway between those of zinc and pure aluminium (see "Corrosion of Metals," A.S.M., 1946, p. 135). Aluminium has, in fact, been alloyed with zinc to make it more anodic in various applications involving sacrificial protection. The addition of silicon to aluminium has no significant effect on such potentials.

The authors indicate on page 113 that the addition of 1% zinc to the aluminising bath would be acceptable. It is, therefore, suggested that coatings made from an Al-Si-Zn bath containing 1% zinc (or perhaps a little more) should be tested in corrosive conditions to see whether they do, in fact, combine some of the advantages quoted, respectively, for the aluminised and galvanised coatings.

The authors aim to achieve a smoother coating by the aluminising process, but for some purposes limited roughness may be desirable. In the absence of further treatment the smooth coating from hot-dip galvanising is not a very satisfactory basis for paint, and aluminising may possibly be superior in this respect, especially with a slightly rough surface. Nodules comparable in height with the thickness of the paint film would, of course, be objectionable in this respect, since they would be liable to carry an inadequate paint film.

Yours faithfully,
F. A. CHAMPION,
Research Laboratories,
The British Aluminium Company, Limited.

Gerrards Cross,
16th November, 1953.

The Editor, METALLURGIA.
Sir,

We are gratified by Dr. Champion's interest in our paper, and we appreciate his helpful comments. There appears to be, however, some misunderstanding regarding the preliminary flash of copper which is applied in some cases. This "replacement" film is exceedingly thin, is probably porous, and is rapidly dissolved by the molten aluminium. This is confirmed by the gradual increase in the copper content of the bath.

We agree that the addition of some zinc is likely to have beneficial electrochemical effects, and one of us (M.L.H.) has already expressed that view at committee meetings when this subject has been discussed. There are two reservations regarding the use of zinc. If thick aluminium coatings are needed it may be necessary to omit the silicon; in such cases only a small amount of zinc is permissible, for otherwise the rate of attack on the basis steel is enormously increased. The use of zinc is also likely to reduce the heat resistance of the aluminium or aluminium/silicon coatings, which is one of their attractive features.

The hot-dip aluminised surface is, as Dr. Champion suggests, superior to a freshly galvanised surface for the application of paint. This is possibly due to the oxide film on the surface. If the coating is cold-rolled or cold drawn to produce more lustre, it is not then suitable for immediate painting.

Yours faithfully,
MARTIN L. HUGHES, D. P. MOSES,
The British Iron & Steel Research Association,
South Wales Laboratories.

Swansea,
24th November, 1953.

January Diary

continued from page 264

26th

Institute of Fuel. "Refractory Recuperators," by F. H. CASS, DR. N. L. FRANKLIN and PROF. A. L. ROBERTS. Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1. 5.30 p.m.

Sheffield Metallurgical Association. Annual General Meeting and Address by the new President, F. H. SANITER. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

27th

Institute of British Foundrymen—Birmingham Branch. "An Approach to Foundry Mechanical Handling," by C. M. G. WALLWORK. James Watt Memorial Institute, Birmingham. 7.15 p.m.

Institute of British Foundrymen—London Branch. "Cast Iron apropos Enamelling," by A. ADAM. Waldorf Hotel, London, W.C.2. 7.30 p.m.

28th

Institute of British Foundrymen—Southampton Section. "General Foundry Problems," by G. J. ROGERS, Southampton Technical College, St. Mary Street, Southampton. 7 p.m.

Institute of Fuel. "Industrial Drying with Particular Reference to the Problems of the Paint and Foundry Industries," by A. M. LEHMANN. James Watt Institute, Great Charles Street, Birmingham, 3. 6 p.m.

30th

Institute of British Foundrymen—Wales and Monmouth Branch. "Some Examples of Core Assembly Methods," by IVOR REES. Newport Technical College, Clarence Place, Newport. 6 p.m.

Metal Casting Methods

IX—Cleaning and Fettling Practice

By J. B. McIntyre, M.Sc., A.I.M.

Senior Lecturer, National Foundry College, Wolverhampton

In the concluding article of the series on metal casting methods, the author considers the operations necessary, after the casting has been removed from the mould, to prepare it for shipment to the customer. These include cleaning off adherent sand and the removal of surplus metal in the form of runners and risers.

CASTING finishing processes can be considered in two main sections, cleaning and fettling. Alloys of high pouring temperature are liable to react with sand moulds, and the relatively low melting point of the bonding material present may cause sand adhesion. Some form of cleaning is then required. Sand adhesion is also influenced by alloy type, casting size and design. Alloys containing appreciable amounts of elements such as aluminium, which forms an adherent oxide film, are not normally susceptible to sand adhesion, and therefore require little cleaning. In contrast, tin bronzes containing phosphorus are more liable to sand adhesion than similar material when free from phosphorus. All cast irons, steels, nickel-base alloys, tin bronzes, and brasses require cleaning, while aluminium bronzes, manganese bronzes, and many light alloys may not require such treatment. In all cases, high pouring temperature, and intricate design, will increase the difficulty.

Very many cleaning methods find application in general foundry practice, and all utilise the common principle of abrasion. In the early days of the industry, rumbling or tumbling barrels were widely used for cleaning sand castings, and still find application in many foundries producing light castings. Such units consist essentially of a cylindrical metal container capable of holding a suitable quantity of castings and abrasive material, and usually designed to rotate about a horizontal axis. In practice, castings and abrasive are brought into intimate contact during rotation, and efficient cleaning is thereby obtained. A wide range of abrasive materials has been used, including white iron shapes of special designs, silica sand, flint pebbles, and broken grindstones. An appreciable amount of cleaning is due to mutual contact between castings, and much skill is often displayed in charging, in order to obtain maximum cleaning efficiency. Excessive packing of castings or abrasive can reduce cleaning efficiency, while insufficient packing can increase breakages. Castings of relatively simple design and large surface area are most suitable for treatment in tumbling barrels, and cleaning is usually of the batch type.

Sand and Shot Blasting

Units were developed in which a stream of sand was directed upon castings by means of compressed air, whilst the barrel was rotating. Cleaning efficiency was thereby increased. Larger static units of the cabinet or room type were designed in order to cope with the cleaning problems associated with the production of large castings. The incidence of silicosis due to sand particles led to the development, some 50 years ago, of metallic shot and grit for cleaning purposes. These metallic abrasives are now widely used. Shot and grit are made from cupola-melted iron of the following approximate analysis: total carbon, 3·3–3·4%; silicon, 1·8–1·6%; sulphur, 0·08–0·1%; phosphorus, 0·9–1·0%; and manganese, 0·4–0·6%. During tapping, a steam jet is directed upon the metal stream, and the latter is converted into pellets of various sizes, which are instantly chilled in a water tank. The hard pellets are then screened into various grades, the oversize or irregular shaped material being crushed into angular grit. Steel wire pellets have been introduced recently, and may eventually replace cast iron grit for many applications. Comparatively soft materials such as corn husks have found limited application in the cleaning of magnesium alloy castings, in order to reduce the possibility of iron pick up.

The equipment used for handling metallic abrasives was essentially similar to that originally developed for sand blasting. Various devices have been introduced to facilitate the handling of castings, yet the orthodox nozzle and hosepipe arrangement used to direct the abrasive stream remains a characteristic of the shot blast cleaning process. Shot blast cleaning is influenced by many factors, and the following are the most important of these: air pressure, air capacity, nozzle bore, type of abrasive, and cleaning technique.

The air pressure used should be as low as possible, since compressed air is an expensive form of power. Excessive air pressure can increase metal losses, and the risk of obtaining poor surface finish on the castings concerned. In extreme cases, distortion has been caused in light castings when unusually high pressure air has been used for cleaning. Experimental work has shown that the air pressure required for the efficient cleaning of similar castings is mainly dependent upon the casting temperature of the alloy concerned: the alloy type will also exert some influence. In practice, compressed air is usually generated at a minimum of 80 lb./sq. in. for general foundry use, and shot blast equipment may be operated from the common supply. It is desirable that cleaning units should be isolated from the common supply, however, since moulding machines particularly cause appreciable fluctuations in pressure.

The type of nozzle used for cleaning exerts a major influence upon cleaning efficiency. Considerable nozzle wear occurs during regular operation, and cleaning efficiency can drop rapidly toward the end of the nozzle life. Chilled iron nozzles are frequently used in jobbing work, and can be cheaply made in the foundry concerned.

Courtesy of F. H. Lloyd & Co.' Ltd.

Removing metal-penetrated sand from a steel casting by the flux-injection method.

Such nozzles must be replaced daily, and wear rapidly toward the end of the day. Superior nozzles made of tungsten or boron carbide and capable of more than 1,000 hours service are available, but the delays involved in maintenance, and the variations in cleaning efficiency due to wear, render airless cleaning methods attractive in mass production plants. Cleaning efficiency is also affected by the type of abrasive and the cleaning technique used. In any given case, it can be demonstrated that an optimum distance and angle exists if maximum cleaning efficiency is to be obtained. In practice, it is unlikely that precise cleaning is obtainable, and the benefits of such techniques may not be realised.

Airless Cleaning Techniques

As the foundry industry gradually expanded, it became apparent that the cleaning methods already established for batch production were not suitable for large mechanised units. Airless cleaning methods were then developed for large plants, but proved equally successful in smaller foundries where the greater cleaning efficiency and comparable costs were attractive. Airless or centrifugal cleaning techniques are now widely used. In these units, a stream of abrasive is propelled at high speed by a rotating wheel ; the latter is normally made of abrasion-resistant cast iron of the Ni-Hard type.

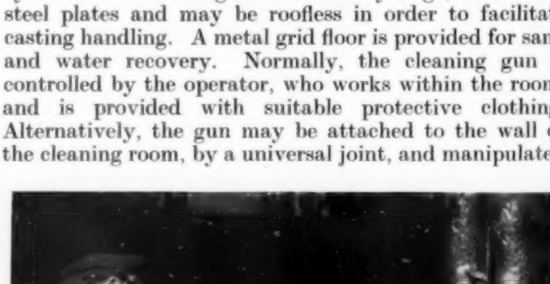
Various designs have been proposed, but two main types find general application. These are the batter and the slider types respectively. The batter type consists essentially of twin blades mounted upon a single metal disc. The abrasive is directed upon the open side of the disc at a pre-determined angle, so that the stream is discharged in the required direction. In the slider type, light blades are fitted between two steel plates, giving a structure similar to a water wheel. Abrasive is fed into the centre of the wheel assembly while the latter is rotating at high speed. A small impeller located in the centre of the wheel assembly and revolving at the same speed receives the stream of abrasive from a feed pipe. Abrasive is passed through an opening in the control mechanism surrounding the impeller, and is finally discharged from the outer edge of the impeller. The speed of rotation is critical, and cleaning efficiency can be impaired if the operating speed is reduced below that recommended by the manufacturers. In each case, the propelling wheel is mounted on a shaft, and the abrasive material can therefore be discharged upon a limited area only.

Centrifugal cleaning devices are apparently not so flexible as are the shot blast units when rubber hose and metal nozzle equipment is standard. In practice, this apparent disadvantage is largely reduced by the provision of suitable equipment for moving castings during cleaning, so that all faces are exposed in turn to the abrasive stream. Castings may, therefore, be tumbled in a barrel-type unit, traversed on a roller conveyor, rotated on a rotary table, or suspended from a pendulum attachment. Rotary table and pendulum conveyor units are probably the most widely used. When large quantities of intricate castings, or castings of large surface area, are to be cleaned, several propelling wheels may be mounted in appropriate positions on the roof and walls of the cleaning chamber. In such cases, cleaning efficiency is markedly increased if the castings are suspended from rotating hangers geared to the conveyors, thereby ensuring that each casting is exposed to the maximum amount of abrasive before removal. Close control over conveyor speed is desirable if excessive cleaning is to be avoided.

Water Cleaning

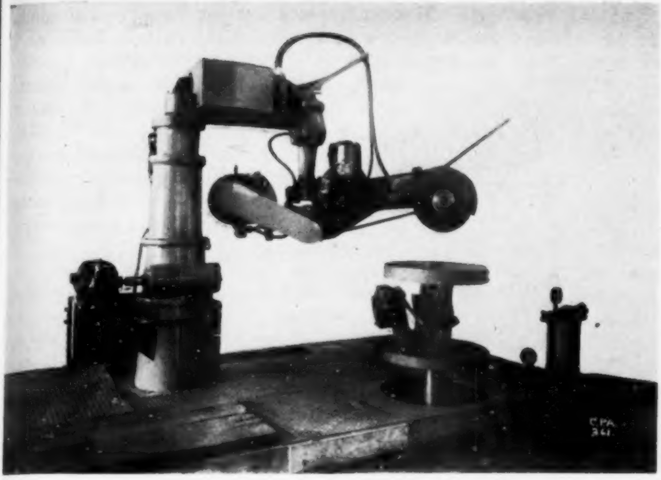
The cleaning of large castings by ordinary methods is a dusty and time consuming operation. Core removal is especially difficult. Tilghman's original patent covered the use of water as a cleaning agent for castings, but practical difficulties prevented the application of this medium, until the Hydroblast system was developed in recent years. The latter technique utilised a water jet at a pressure of 1,200 lb./sq. in. and containing a quantity of sand. This combination proved to be very effective, promoting rapid cleaning, under virtually dust-free conditions.

The Hydroblast plant consists essentially of a cleaning room, the cleaning gun, and the sand reclamation system. The cleaning room is usually large, made from steel plates and may be roofless in order to facilitate casting handling. A metal grid floor is provided for sand and water recovery. Normally, the cleaning gun is controlled by the operator, who works within the room, and is provided with suitable protective clothing. Alternatively, the gun may be attached to the wall of the cleaning room, by a universal joint, and manipulated



Courtesy of F. H. Lloyd & Co., Ltd.

Removing feeding heads by oxy-acetylene cutter.



Courtesy of Tabor Manufacturing Co., Ltd.

Above—Universal cut-off machine.

Right—Band saw fettling of pure copper sand castings.

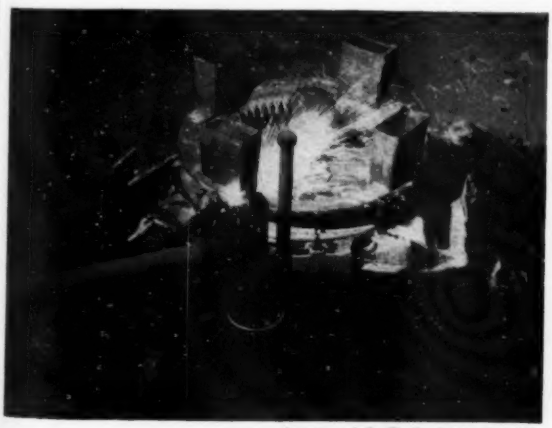
Courtesy of J. Stone & Co., Ltd.

by the operator from outside the room. Modern practice favours the use of even higher pressure jets, capable of passing greater quantities of sand.

In the Hydroblast plant, both water and sand are recovered, and the latter feature is particularly attractive where sand costs are high, and facilities for disposal are limited. Installation costs are substantial, but plants of this kind are widely used in foundries concerned with the production of medium and large castings.

Fettling

When a shaped casting is removed from the mould and cleaned, a sequence of additional operations is usually required in order to remove the running and risering system. These operations are known collectively as "fettling," and include all techniques used for superfluous metal removal. As in all other phases of casting production, casting size and alloy type are controlling factors. The latter is of primary importance. The oxy-acetylene cutting techniques which are so widely applied to the majority of steel castings, are relatively ineffective



Courtesy of F. H. Lloyd, & Co., Ltd.

Oxy-acetylene burning-off machine.

BAND SAW DATA FOR FETTLING CASTINGS*

Material	Number of Teeth per inch.	Speed of Blade in feet per inch
Steel	10–12	150–200
Malleable Cast Iron	12	150–200
Manganese Bronze	10–12	150–200
Brass	12–14	150–200
Grey Cast Iron	12–14	100–150
Copper	10–12	200–500
Aluminium Alloys	8	2,000–5,000
Magnesium Alloys	4–6	2,000–5,000

* Courtesy Edgar Allen, Ltd.

when used on nickel-base and copper-base alloys. Similarly, the knock-off methods which find general application in the fettling of light iron castings, cannot readily be used for the more ductile foundry alloys. In any given case the method chosen will be that capable of removing the excess metal most economically.

Economics are closely linked to production time, and fettling techniques must be closely studied if maximum output is to be maintained. Cleaning and fettling often cause bottlenecks in regular production when incorrect methods are used. No ideal method is available, since both cutting off and grinding operations are normally required. It is very difficult to avoid grinding completely, but this operation should be restricted, as far as possible, since it is probably the most expensive method of removing metal in bulk. In isolated cases it may be possible to combine fettling with one of the machining operations which are often applied to castings.

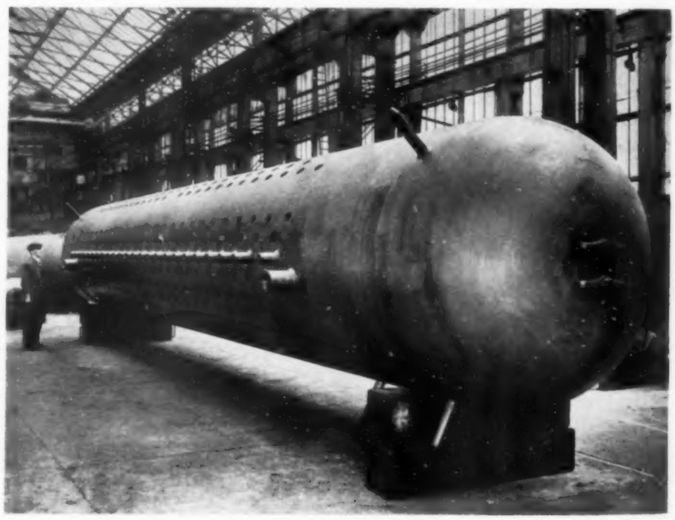
"Knock-off" methods are quite effective for brittle materials of relatively thin section, and are also successfully applied to larger sections when "necked down" risers have been used. Alternatively, the substantial feeding systems applied to large grey iron castings can be removed by machining, or by the comparatively slow moving, lubricated circular saws which are known as "cold saws." Copper-base and nickel-base alloy

castings may also be fettled with this equipment. Pneumatic chisels find useful application in the same field as "cold saws." Band saws are widely used in the fettling of light alloys, and for thin sectioned copper-base and ferrous materials. Experience has shown that a specific type of saw is required for each type of alloy if maximum cutting efficiency is to be obtained. The high speed friction saws which have appeared in recent years may be regarded as special purpose circular saws.

Hard or tough materials provided an awkward fettling problem until the abrasive cut-off wheel was developed. Both table and chopper types of cutting-off machine now find wide application, and are the most suitable units for rapid fettling within the limits imposed by wheel diameter. The universal cut-off machine illustrated successfully overcomes the difficulties encountered in the normal static cutting-off machines, since it is extremely flexible in use. The steel castings industry owes much to the development of oxy-acetylene cutting methods, and it is unlikely that the substantial feeder heads which are a feature of steel foundry practice could be economically removed by any of the alternative methods. If an adequate oxygen supply is available, any commercial thickness of plain carbon steel can be cut by oxy-acetylene equipment. Certain types of alloy steel, notably the chromium-nickel stainless varieties, do not respond to such treatment, and are difficult to fettle by orthodox methods. The recently developed powder or flux injection techniques have been successfully applied to this fettling problem, and have also been effective in removing the metal-penetrated sand which is occasionally encountered in steel castings, and has long been a problem.

When the cutting-off operations are completed, additional dressing with pneumatic chisels may be applied to medium or large castings. The grinding operation may be carried out on pedestal type grinding machines if small castings are involved, or by portable grinding equipment, if medium and large castings are concerned. Swing-frame type grinders are widely used for heavy castings. Grinding is similar to band saw cutting, in that almost any type of grinding wheel can be used, but maximum efficiency and low costs, can only be achieved if the appropriate type of wheel is used for the alloy concerned.

Sheffield Produces Record Hollow Forging



THE largest forged steel boiler drum ever made in one piece was delivered recently to a new Tyneside power station. Made at the River Don Works of English Steel Corporation Ltd., with a length of 42 ft., an outside diameter of 6 ft. 2¼ in. and an internal diameter of 5 ft. 6 in., this drum has the greatest capacity of any hollow forging ever produced without welding.

The drum, which has been tested to withstand a pressure of 1,740 lb./sq. in., though the working pressure will be 1,160 lb./sq. in., has a wall thickness of 4⅛ in., which increases to over 7 in. at the ends. When ready for despatch, with all the tube holes drilled and the 33 nozzles fitted, it weighs 63 tons (approximately). To make the forging, a 153-ton billet was produced from an ingot of 217 tons made from three large furnaces in the Siemens acid open hearth plant. It was forged into shape under a 7,000 tons electro-hydraulic forging press, the largest of its kind in Great Britain, operating at a pressure of 2¼ tons/sq. in.

To deal with a forging of such dimensions, machine tools of exceptional size and capacity are required. In the central machine shops at River Don Works, with nearly a mile of bays under one roof, and with a floor space of 230,000 sq. ft., is assembled a range of equipment considered by many to be the finest of its type anywhere.

Amongst the machines there is a 72 in. lathe driven by a 450 h.p. motor and others, capable of taking drums up to 60 ft. in length, which will remove four tons of steel turnings in an hour. A double-ended boring machine, 190 ft. long, will bore simultaneously two drums up to 7 ft. in diameter. There are also vertical borers, shapers, slotters planers and smaller lathes to deal with the whole range of forgings produced by E.S.C.

Recently, a similar, but smaller drum, 5 ft. in diameter and 42 ft. long, was despatched to the same power station. This was notable for the fact that it contained 81 nozzles. These two drums comprise the first of four similar sets being made by E.S.C. for the B.E.A.'s two new power stations on the North and South Banks of the Tyne. The drums will be suspended at a height of more than 100 ft. above floor level.

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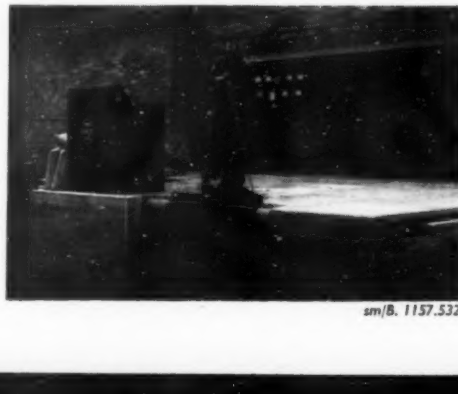
Inset top: pouring one of the furnaces; hydraulic tilting mechanism is used.

Inset bottom: the furnace platform showing control desk and instrument panel.



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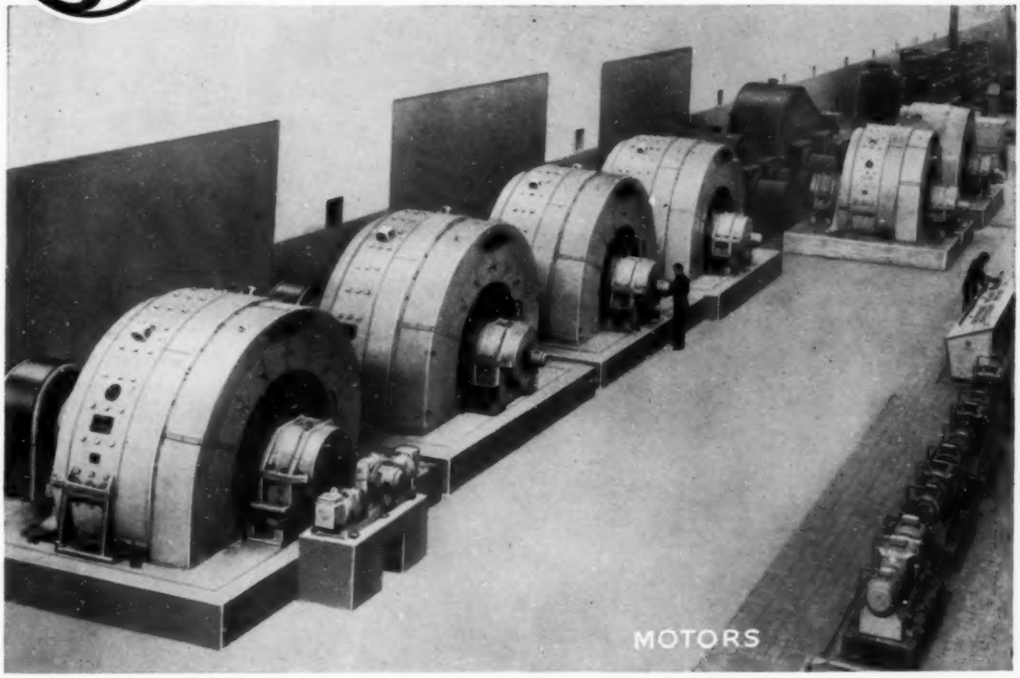

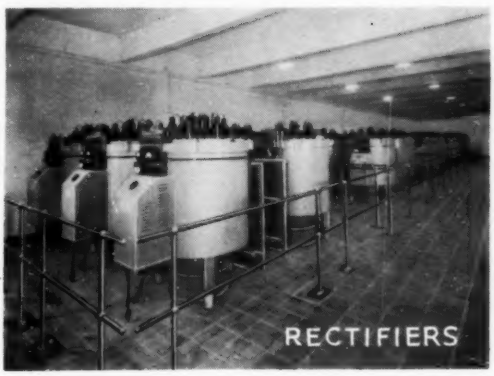

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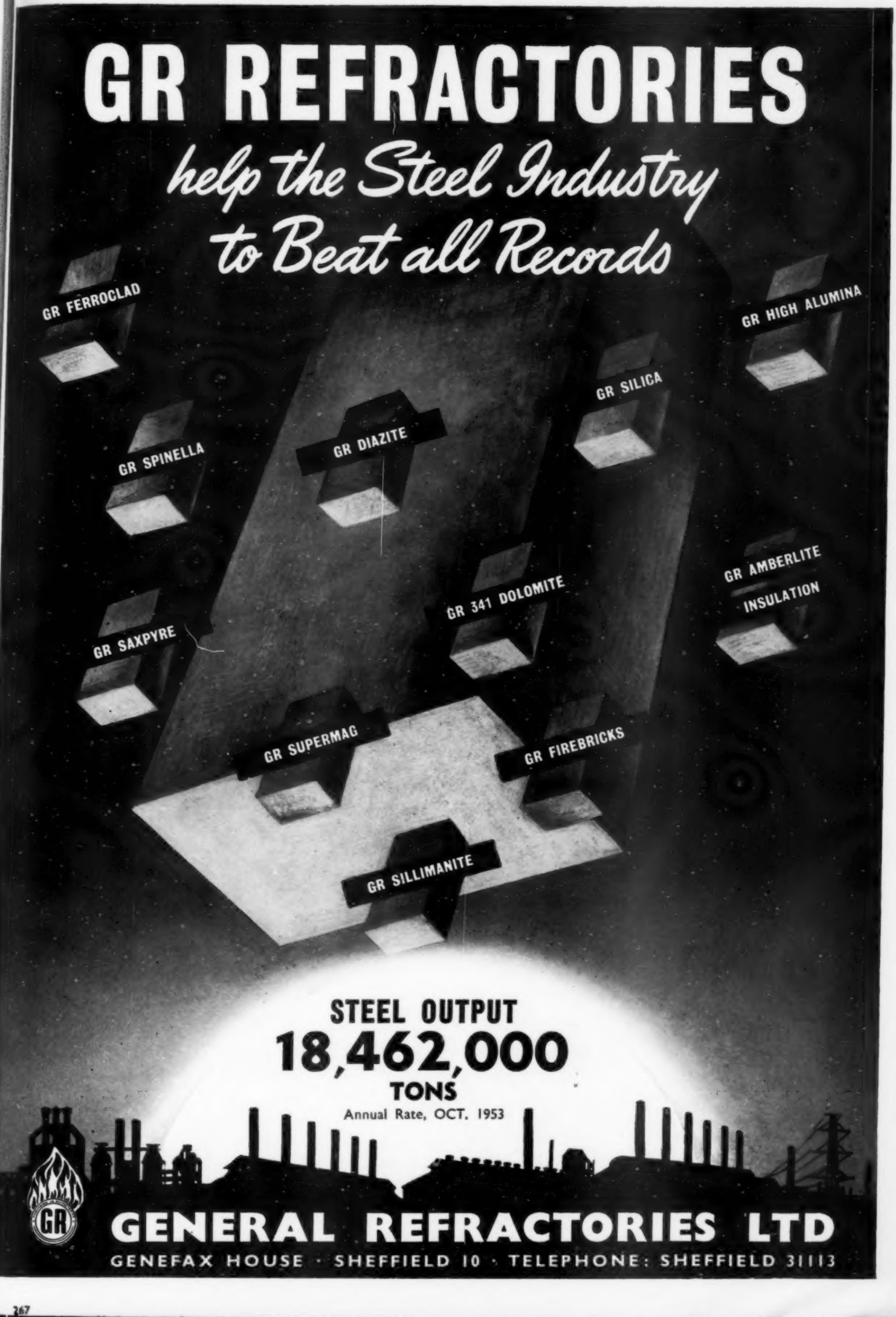
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Developments in the Metallurgy of Tin and its Alloys

By J. W. Cuthbertson, D.Sc., F.I.M., A.M.I.E.E.
Assistant Director of Research, Tin Research Institute

Now that tin is more freely available throughout the world, advantage will more readily be taken of the recent metallurgical advances involving the use of this metal. This review is devoted to a discussion of recent progress in tinplate production, ternary alloys, aluminium-tin bearing alloys, and the electrodeposition of tin-zinc and tin-nickel alloys.

WORLD production of tin in concentrates in 1952 was 171,000 tons, an increase of 4,500 tons on the figure for 1950.[1] Of the total tin consumption, by far the biggest proportion is used for the manufacture of tinplate : other important applications include the production of bronze, solder and bearing alloys. Since the previous review was published in 1950,[2] noteworthy developments have occurred in the production of tinplate, but nothing of outstanding importance can be reported with regard to progress in the bronze and solder fields. On the other hand, during this period some interesting new ternary alloys of tin have been investigated, and advances have been made in bearing alloys. Considerable progress has also been made in the electrodeposition of tin alloys. Tin-zinc alloy plating, introduced some years ago, has made still further headway, and a new process, tin-nickel alloy plating, has passed from the laboratory stage into commercial operation. These are the major advances that mark the past three years, and this review will mainly be confined to a discussion of them.

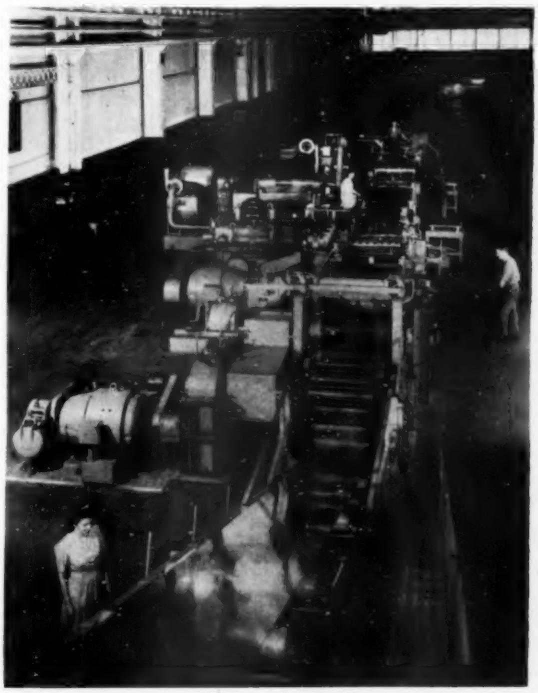
Tinplate

Tinplate production continues to increase. In 1950 world production was 5,750,000 tons. Production in 1953 should surpass 6,000,000 tons, and further planned expansion will, it is estimated, raise production capacity to 8,000,000 tons by 1961.[3] The outstanding development in this application of tin is the steadily increasing use of the electrolytic coating process. However, the older hot-dip process is still extensively used, and recently new and up-to-date hot-dipping plant has been installed in this country, in Holland, in Belgium and in South Africa.

The electrolytic tinplate process has become popular for two main reasons. First, the process is fast and continuous, and is thus easy to integrate with the modern cold reduction mill, which produces steel strip at very high speeds. Second, by electrodeposition thinner coatings than are possible by hot dipping can be applied, and a very close control over coating weight can be maintained. In 1950, nearly 60% of the tinplate produced in the United States was electrolytic : in June, 1953, this figure had risen to over 70%. In Great Britain, during the same period, electrolytic tinplate production soared from 9·5% to 22% of the total output. Overall production of tinplate is increasing, and these figures do not mean that the increase in the production of electrolytic tinplate has been wholly at the expense of the hot-dip process ; on the contrary, the production of hot-dipped tinplate in the past two or three years has remained at a fairly steady level.

In the last three years, further electrotinning lines have been erected in the United States, in Canada, and in Great Britain. The expansion in South Wales, referred to in the preceding review, has brought into operation two further lines, bringing the total up to three. The two new lines have been installed at the Trostre Works of the Steel Company of Wales. An electrotinning line has been erected and is now operating at the Liège Works of Ferblatil, and another line is in course of construction in France. Further expansion on the continent is envisaged.

In the United States, four different electrolytes are in use for continuous electrotinning, but only one of these, the Ferrostan solution based on stannous sulphate



Courtesy of Wean Engineering Co., Inc.

Fig. 1.—Ferrostan electrotinning line. Exit end showing emergent flow-brightened strip.

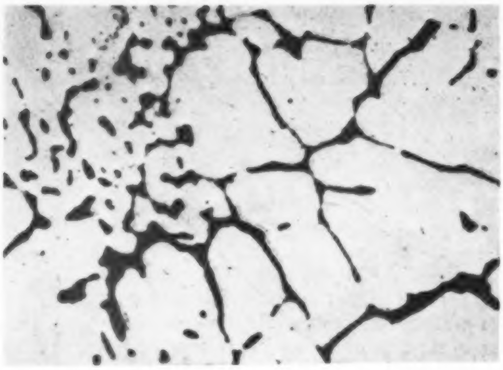


Fig. 2.—Binary aluminium—30% tin alloy showing the continuous network of tin typical of the "as-cast" structure. × 250

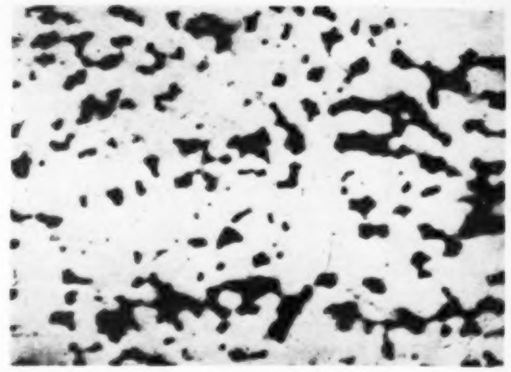


Fig. 3.—The same alloy as that shown in Fig. 2 after cold working 20% and annealing for 1 hour at 350° C. to re-crystallise the aluminium. × 250

and developed by the United States Steel Corporation, has been used in plants erected outside that country. A typical view of a Ferrostan line is shown in Fig. 1. Full descriptions of continuous electrotinning procedure have been published on numerous occasions, and it is only necessary here to say that in this process the steel strip is cleaned, pickled, plated, and the matt tin deposit flow-brightened as one continuous operation. The plated strip is finally either coiled or sheared into sheets of the desired size. The average rate of processing to-day is probably around 650 ft./min., but in the United States, using a suitable electrolyte, speeds of up to 2,000 ft./min. are being approached. At such high speeds, shearing while the tinplate is moving becomes impossible, and the emergent strip is, therefore, coiled and cut up as a subsequent operation.

Differentially-Coated Electrotinplate

A recent development in connection with continuous electrotinning is the manufacture of tinplate carrying a different tin coating weight on each face. The bulk of tinplate is made into cans, and the tin coating thickness is specified according to the nature of the pack to be preserved. The outside of the can is usually less a matter of concern than the inside, which is in contact with the pack ; the outside, moreover, is often protected by some decorative finish. Tin may thus be conserved by putting less on the outside than on the inside of the can. By plating each face of the strip separately in a horizontal cell, or by appropriate adjustment of the current in a vertical cell, feeding more to one face of the strip than to the other, differential coatings can readily be achieved. Tinplate thus coated has been on the market in the United States since 1951, but, so far, differentially coated tinplate has not been manufactured commercially elsewhere.

According to requirements, the ratio of the coating weights on this type of tinplate can be varied, for instance, from 1 : 2 to 1 : 4, the higher ratios in general applying to the heavier internal coatings. However, the only grade of material that has so far been used to any extent is that carrying the equivalents of 4 oz. per basis box (0·000015 in.) on the one face and 16 oz. per basis box (0·00006 in.) on the other. Such material is being used in the United States, mainly for tomato cans. The saving in tin resulting from the differential procedure is said to be from about 17% upwards, depending on the selected thickness combination.[4] While the saving in tin must be admitted, it does not follow that this process necessarily effects an overall reduction in the cost of the container. An additional expense is introduced in providing some means of identifying one face of the tinplate from the other. Such identification is clearly essential, as a reversal of the surfaces by the can maker could have disastrous results. A number of marking procedures have been investigated, but no entirely satisfactory one has yet been devised. A further consideration is the possible necessity for applying increased protection to the outside of cans made from stock carrying only 4 oz. per basis box on the outer face, in order to ensure adequate shelf life. Although this new material has made some headway it is clearly, in view of these factors, too early to predict its future.

Tin in Substitutes for Nickel-Containing Copper-Base Alloys

In an attempt to find substitutes for copper-base alloys containing nickel, which is a strategic metal and has been in short supply for non-essential uses, the possibilities of substituting tin for some or all of the nickel have been examined. A ternary alloy containing copper, nickel, and tin has been found to possess properties close to those of cupro-nickel of considerably higher nickel content, while an alloy of copper, manganese, and tin has been developed that closely resembles nickel silver.

In seeking a substitute for cupro-nickel, particularly for coining and stamping work, colour is almost as important as ductility and mechanical strength. A much favoured alloy for this class of work is one containing 75% of copper and 25% of nickel. This alloy has a hardness of 90 in the as-cast condition and about 70 in the fully annealed condition. It has been found that 10% of the nickel in this alloy can be replaced by 5% of tin without much sacrifice of colour or mechanical properties.[5] The resulting ternary alloy, containing 15% of nickel and 5% of tin, has a minimum hardness of 88 and is almost as white as the 25%-nickel binary alloy. If this minimum hardness is too high, as it may be for some deep embossing operations, it can be reduced to about 74 by lowering the tin content to 3%. but at the expense of some deterioration in the colour, which now becomes slightly yellow.

The ternary alloys containing more than 3% of tin can be hardened by precipitation, and this may be an

advantage as it affords a means of hardening after stamping, and thus of increasing resistance to deformation, wear and abrasion. When quenched from 750°–780° C., these alloys consist entirely of the *alpha* phase and, in consequence, are in their softest condition. The alloy containing 5% of tin, when slowly cooled from a temperature above 750° C., precipitates the hard *theta* phase (a compound of tin and nickel, probably Ni_3Sn) and marked increase in hardness results. The maximum hardness attainable in this way approaches 250. If the tin content is reduced to 3%, the resulting alloy is brought very close to the *alpha* phase boundary at room temperature, and on slowly cooling, the *theta* phase may or may not precipitate, according to whether the tin content happens to be just above or just below this figure.

Neither of these alloys is offered as a perfect substitute for cupro-nickel, but they are claimed to approach it sufficiently closely to warrant their serious consideration, especially as they substantially conserve nickel.

An alloy of copper with about 15% of manganese and 6% of tin is said to be an attractive alternative to nickel silver. In the soft condition, alloys around this composition can be rolled and stamped without difficulty, and, as the alloys are susceptible to precipitation hardening, subsequent heat treatment can be carried out if desired. Casting of the alloys apparently presents no especial difficulties. The reported work on this alloy system[6] refers to alloys made up from electrolytic manganese, but it is understood that the possibilities of using commercial ferro-manganese are now being investigated with a view to lowering the price of the alloy to about the same as that of nickel silver.

These new manganese-containing alloys are showing considerable promise, and preliminary trials have indicated that they can be handled with the same facility as nickel-silver. In resistance to tarnishing, they compare favourably with nickel-silver, and it is envisaged that they may find an outlet in the manufacture of spoons, forks, cigarette cases, etc. No difficulty arises in electrodepositing silver or other finishes on them.

Tin in Copper-Beryllium Alloys

Copper-beryllium alloys, as used for high-duty springs, can be cheapened by substituting tin for some of the beryllium, which can apparently be done without serious deterioration in mechanical properties.[7] This is illustrated by the figures given in Table I.

TABLE I.—EFFECT OF TIN ON HARDNESS OF COPPER-BERYLLIUM ALLOY

Composition of Alloy	Vickers Hardness Number			
	Annealed	Cold Rolled	Heat Treated	Heat Treated after Cold Rolling
97·5% Cu—2·5% Be ..	80–100	215–240	375	390
90·25% Cu—9% Sn—0·75% Be	130	290–300	260	402

The ultimate tensile strength of the above ternary alloy is around 110,000 lb./sq. in. So far as tensile strength and hardness are concerned, the ternary alloy compares favourably with the higher-beryllium binary alloy. However, no data are available on the fatigue and corrosion-fatigue resistance of the ternary alloy, and this information is needed before a full comparison can be made. The tensile properties of the ternary alloy are inferior to those of the copper-beryllium-cobalt (or nickel) alloys containing 2% of beryllium. This type of alloy is likely to be retained for the more stringent uses, but for less severe duties the tin-containing alloy, owing to its much lower cost, might be an attractive alternative. This assumes, of course, that its resistance to fatigue proves to be adequately high.

Aluminium-Tin Bearing Alloys

Tin alloys have always been popular for bearings. The tin-base Babbitts have excellent anti-friction properties, and are still extensively used whenever bearing loads are within their safe range. In all respects but one, these alloys are the best plain bearing materials that have yet been devised. Their use is limited, however, to applications where the maximum load does not exceed 2,500 lb./sq. in., and if speeds and temperatures are high the maximum safe load is nearer 2,000 lb./sq. in. At higher loads, failure occurs through fatigue, and so far no method of substantially raising the fatigue limit of Babbitt-type alloys has been discovered. For higher loads, much use is made of copper-lead alloys, but these leave something to be desired. In particular, they are somewhat hard as compared with Babbitt and tend to cause journal wear.

Several alternatives to copper-lead bearing alloys have been suggested, amongst which aluminium-tin alloys have met with some success. The commercial alloys of this type contain 6–7% of tin, with a little nickel and copper, and have a hardness that may run as high as 80. The tin confers the anti-friction properties, but as the tin content is small, particularly when reckoned on a volume basis, it is to be expected that the alloy will be inferior to Babbitt as a bearing material. If the tin content could be increased, a better bearing material should result: it has been shown that resistance to scuffing increases with tin content.[8] Until recently, it was not practicable to raise the tin content above about 7% because higher tin alloys have poor physical properties at bearing temperatures. Tin and aluminium are mutually almost insoluble in the solid state, and alloys containing 10% or more of tin consist of primary crystals of aluminium surrounded by continuous films of tin. It has recently been discovered that by cold working such cast aluminium-tin alloys, and then heating to 350° C. to recrystallise the aluminium, the tin films can be broken up and the tin dispersed in a more or less spheroidised form.[9] By adopting this procedure, it is possible to increase the tin content to as much as 50%, and still to maintain good strength and ductility at operating temperatures. The improvement in structure obtained in this way will be apparent from a comparison of Figs. 2 and 3. Good bearing properties can be obtained with considerably less than 50% of tin, and in fact such a high tin content would not be very practicable, as, with more than about 30% of tin, it is difficult to avoid appreciable loss of tin through bleeding out during the recrystallisation heat treatment. Experience has shown that 20% of tin meets most requirements although for special purposes a figure of 30% might be preferable.

Binary alloys of this type are soft, their Vickers hardness being in the range 25–30. Addition of copper hardens the alloys, but the hardening effect is not great unless more than 1% of copper is added and appropriate

Fig. 4.—Underwood bearing testing machines installed in the laboratories of the Tin Research Institute.

heat treatment applied.* With 3% of copper, the matrix can be solution heat treated and aged just as duralumin can, and in this way the hardness of the alloy can be raised to about 80 Vickers. A wide range of hardness values is thus available, merely by slightly varying the alloy composition and adjusting the heat treatment.

Better Fatigue Properties

These new alloys are attractive because they have good anti-friction properties ; for parallel performance are softer than copper-lead ; have high fatigue strength ; and are relatively cheap. Compared with Babbitt, the soft binary alloys have approximately double the fatigue strength at 150° C., and when it is realised that the hardnesses of the tin-base and aluminium-base alloys are similar, this is a very noteworthy and significant improvement. The harder, ternary alloys are somewhat stronger in fatigue than the binary alloys, but increase in hardness, which is accompanied by considerable increase in tensile strength, does not lead to directly proportionate increase in fatigue resistance. The fatigue performance is probably linked with the tin content of the alloy, and hardening of the matrix, as it can have no effect on the tin, would not be expected markedly to influence this factor. To be able to harden the alloy as desired is a big advantage, however, as it enables the strength of the alloy to be adjusted according to the load that the bearing will have to withstand in service. The maximum fatigue strength obtainable for alloys containing 30% of tin and 3% of copper in the matrix, fully heat treated, is about 5,400 lb./sq. in. at 150° C., and this is adequate to meet most present-day requirements.

Extensive laboratory tests have been carried out on these bearings during the past two years. Experimental bearings tested in the Underwood type of machine have behaved very satisfactorily, showing excellent resistance to fatigue and low shaft wear. The Underwood machine, two examples of which are shown in Fig. 4, simulates the conditions prevailing in the big-end bearing of an internal combustion engine, and is generally conceded to be one of the most reliable bearing fatigue testing devices. The bearings that have been tested were in some cases solid, i.e., unbacked, and in others backed by steel. The softer alloys cannot be used as solid bearings except for low loads, because they deform plastically under heavy stresses unless used as thin layers, say 0·02 in. thick, bonded to a stronger material. The bonding of these alloys to steel presents considerable difficulties, and so far this problem has not been completely solved. Progress has been made, however, and small bearings about 1·25 in. wide and 2·5 in. bore have been bonded to steel sufficiently strongly to enable them to be tested in the laboratory machines. The bonding of these alloys to duralumin is practicable, and bearings of this type are now available from one manufacturer. Engine tests on duralumin-backed bearings containing 20% of tin have given most encouraging results.

These new bearings have been developed primarily as alternatives to copper-lead. They are showing considerable promise and, in fact, mark one of the most noteworthy advances in the bearing field in recent years. Their future is assured, but the extent to which they are likely to be used depends on whether or not they can be satisfactorily bonded to steel. Although the harder alloys are attractive, and superior to the lower-tin alloys of similar type at present in commercial use, full advantage of the unique combination of softness and high fatigue strength that the binary alloys provide can only be taken by bonding them to a strong backing. Duralumin meets requirements up to a point, but the duralumin-backed bearing still has a high coefficient of expansion as compared with steel. This may make it difficult to maintain a proper interference fit between such a bearing and a ferrous housing.

Tin-Zinc Plating

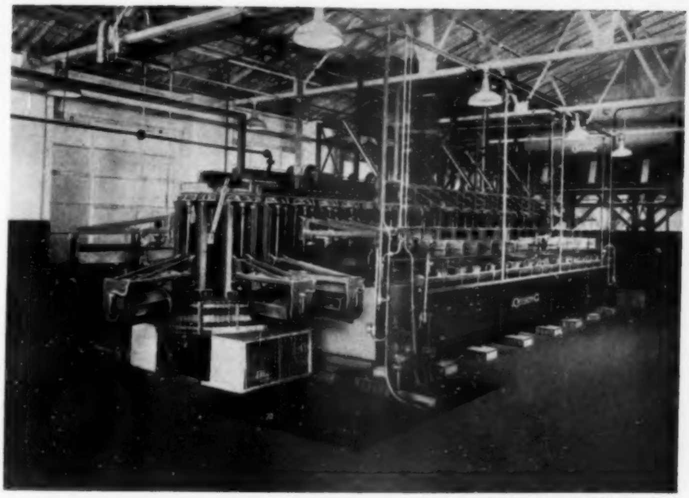
The tin-zinc alloy plating process, which was introduced some seven years ago for the protection of steel against corrosion, has made further substantial progress in the last few years. In addition to several smaller plants, one having a capacity of 2,800 gallons, of the semi-automatic type, has just come into operation for the plating of evaporators for refrigerators. The applications of tin-zinc plating are expanding rapidly. New uses include, in addition to that just mentioned, the protection of aircraft under-carriage parts, of steel pressings for automobile electrical equipment, and of brass tubes for coolers.

This plating process is mainly used as an alternative to cadmium plating. Except under severe marine conditions, where tin-zinc shows no particular superiority to cadmium, tin-zinc affords better protection than cadmium, and has the advantage of being a cheaper coating.

Owing to its excellent solderability tin-zinc is favoured by the electrical industries, and in some cases is being now used as an alternative to zinc. While tin-zinc is anodic to steel, it is mildly cathodic to aluminium. A new use of the coating now being investigated is for the protection of steel nuts and bolts for use in contact with aluminium.

* The copper is entirely present in the aluminium matrix. The copper contents quoted throughout this section relate to the percentages of copper in the aluminium and not in the alloy as a whole.

Tin-zinc can be barrel plated, but until recently the barrel process was operated only on a relatively small scale. During the present year, a large, fully automatic barrel plant has come into operation for the plating of small steel pressings. A plant of this type is shown in Fig. 5. This plant, like all others so far installed here and on the continent, uses the original electrolyte containing sodium stannate, sodium hydroxide, sodium cyanide, and zinc cyanide. An all-potassium bath has been developed in the United States by the Metal & Thermit Corporation, and is claimed to be capable of operation at higher current densities than the all-sodium bath.



Courtesy of W. Canning & Co., Ltd.

Fig. 5.—Automatic barrel plating plant as used for tin-zinc alloy plating.

Tin-Nickel Deposits

A process for co-depositing tin and nickel in approximately equi-atomic proportions has recently been invented, and is now in commercial operation.[10] The electrolyte contains the two metals as chlorides, and fluorides are added to exert a complexing action. The deposit contains around 65% of tin and 35% of nickel, and is a single phase compound of formula NiSn. The plate deposits in an almost bright form, requiring very little buffing. The interesting feature of this new deposit is its very high resistance to tarnishing and corrosion, in which respect it is as good as, or even superior to, chromium. The plate has a most pleasing colour, and is characterised by a faint pink tint. It is serviceable for use indoors or out-of-doors, and is already finding a useful outlet for finishing a variety of articles. As the process is, however, comparatively new, it will be some time before its sphere of application becomes completely defined. At the moment, it is mainly being used for finishing domestic articles.

Metallographically, electrodeposited tin-nickel is most interesting, as it is an example of an alloy that cannot be produced by any other known method. The alloy is metastable and can be regarded as a modification of the stable phase Ni_3Sn_2, in which vacant sites in the lattice are occupied by additional tin atoms. Although the deposited alloy is metastable, it does not recrystallise below about 300° C.[11] At lower temperatures, it is permanently stable, and the fact that it is in theory metastable does not therefore detract from its serviceability. Above 300° C. the alloy decomposes into a mixture of Ni_3Sn_4 and Ni_3Sn_2 with a volume change.

Compared with chromium deposited over nickel, this new plate offers the advantages of one plating process as against two, and of effecting a saving in nickel. The plate can be deposited direct on copper and on most non-ferrous alloys, aluminium and zinc-base alloys excepted. In the case of steel, the use of a copper undercoat is recommended. Aluminium and zinc are attacked by the tin-nickel electrolyte, but can be plated if first protected by depositing a continuous coating of either copper or nickel. A feature of the tin-nickel process is the constancy of composition of the deposit; this, coupled with the high throwing power of the electrolyte, makes the process attractive from the viewpoints of ease of control and uniformity of the deposit.

Tin and antimony have been co-deposited from a solution constitutionally similar to that used for co-depositing tin and nickel, but containing antimony trichloride in place of nickel chloride.[12] This process may have possibilities in connection with bearings, and its potentialities in this direction are being investigated.

Conclusion

The developments referred to above represent the high lights in the progress of the metallurgy of tin and its alloys during the last three years. Minor developments have not been reported, and in the space available it has not been possible to refer to research projects of the more academic type. Tin possesses some unique properties, and interest in the exploitation of the metal and its alloys remains unabated. Now that the metal is freely available throughout the world we may look forward to still further advances in future years.

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New Edgar Allen Tool Factory

Edgar Allen & Co., Ltd. announce that their new Engineers' Tool Factory, at Shepcote Lane, Tinsley, began operation on October, 19th, 1953. The factory has been built to manufacture many types of tools, including butt-welded cutting tools; precision ground form tools; tungsten carbide tools and tips; high speed steel tool-holder bits; Athyweld deposit-welded tools; and high speed steel faced wood-working knives, etc. The factory has been laid out on the most modern lines for progressive mass production, on a separate plot of land just beyond the existing large trackwork manufacturing department at Shepcote Lane. It is a single storey building, 230 ft. long × 160 ft. wide, covering 37,000 superficial feet of floor area. The factory has been built to meet steadily increasing demand, extension of the original Engineers' Tool Department being no longer possible without encroachment on neighbouring departments.

The Present Status of Magnesium and its Alloys

By R. G. Wilkinson, B.Sc.
Magnesium Elektron, Ltd.

Although Britain is less favourably placed than some other countries in the field of primary production of magnesium, it occupies a leading place in magnesium alloy technology. In this survey of recent developments, particular attention is given to the casting alloys containing zirconium and thorium, which have greatly improved properties at elevated temperatures.

WHEN the status of magnesium and its alloys was last reviewed in this journal two years ago, war surplus stocks of primary metal were approaching exhaustion and, under the stimulus of the Korean crisis, a number of extraction plants had just been, or were being, re-opened in the U.S.A., Canada, Norway and other countries. In the U.K., where the Clifton Junction plant of Magnesium Elektron, Ltd. had been idle since the shut-down during the fuel crisis of 1947, virgin magnesium and magnesium alloys had once more been placed under official control, and the plant brought into operation again on Government account.

Following repletion of stock piles and easement of the Korean situation, nearly all the rehabilitated Government-owned plants in the U.S.A. have again been closed, and in October last the U.K. Government announced that, from January 1st, 1954, virgin magnesium and primary alloys would be freed from control, and that Government support of domestic production would be withdrawn shortly afterwards.

In considering the future of U.K. magnesium production, it must be recognised that, whereas in the U.S.A. there is an outstanding record of price stability (at least as far as private enterprise production is concerned), and whereas Canada and Norway are low cost producers, this country is placed at a serious disadvantage in primary production by the high cost of the electricity needed in electrolytic extraction, which has to date been easily the most economic process. The cost of electricity represents a significant percentage of the total cost of production, and as the price of electricity is now four times the pre-war figure, the U.K. is badly placed, compared with certain other countries, in world competition. This is a difficult situation; however, with the resumption of private trading, there are grounds for hope that satisfactory arrangements can be made to continue production and supply under free enterprise.

M.E.L. has for some years been pursuing research on extraction processes alternative to the electrolytic method, and which could be largely independent of electricity supplies. The results of these investigations are promising, and needless to say the work is being pursued very actively.

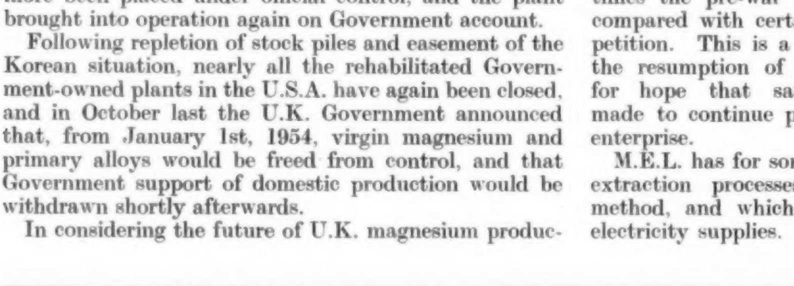

Fig. 1.—High-speed warping beam with 30 in. diameter flanges and 10 in. diameter barrel cast in " C " alloy.

Reference should be made to other articles[1,2] for detailed accounts of the magnesium production situation at home and abroad.

If Britain is less fortunately placed than some other countries in the field of primary production, this is certainly not the case in the development of new alloys. Indeed, it can justly be claimed that, as a result of many years of persistently vigorous chemical and metallurgical research, Britain now leads the world in magnesium alloy technology, and M.E.L.'s zirconium alloying and zirconium- and thorium-containing alloy patents are being operated under licence by leading foundries in America, Canada, Australia, France, Switzerland, Holland, Sweden and Italy. The associated royalties and exports of special salts, fluxes and (in most cases) metal are significant.

TABLE I.—PROPERTIES OF ZIRCONIUM-CONTAINING CASTING ALLOYS AT NORMAL TEMPERATURE

Alloy	D.T.D. Specification	Tension			Compression		Brinell Hardness (500 kg., 30 sec., 10 mm. ball)	Fatigue (Wöhler 50×10^6)		Impact (Hounsfield)		Alloy
		0·1% Proof Stress tons/sq. in.	Ultimate Stress tons/sq. in.	Elongation % on 2 in.	0·1% Proof Stress tons/sq. in.	Ultimate Stress tons/sq. in.		Un-notched tons/sq. in.	Notched (S.C.F. = 2) tons/sq. in.	Un-notched ft. lb.	Notched (equivalent to Izod) ft. lb.	
Z5Z Heat Treated	721	8·5–10·5	15·0–18·0	5–12	9·0–11·0	23·0–27·0	65–75	5·0–5·5	4·8–5·5	5·0–9·0	2·0–3·0	Z5Z Heat Treated
As Cast	711	7·0– 8·5	13·0–17·0	7–15	7·0– 8·0	22·0–24·5	55–65	4·8–5·3	3·8–4·3	8·0–11·0	2·5–3·5	As Cast
RZ5 Heat Treated	000 (Draft M33)	8·0– 9·0	13·5–14·5	3–5	7·5– 9·5	21·5–23·5	65–75	6·0	5·0	3·0–4·0	0·5–1·5	RZ5 Heat Treated
ZRE1 Annealed	000 (Draft M21)	5·0– 6·0	9·0–11·0	3–6	5·0– 7·0	18·0–22·0	45–55	4·3–4·8	3·3–3·8	4·5–5·5	0·5–1·5	ZRE1 Annealed
MCZ Annealed	000 (Draft M23)	5·0– 6·0	9·0–10·5	3–6	6·0– 7·0	18·0–22·0	45–55	4·2	3·5	—	—	MCZ Annealed
ZT1 Annealed	—	5·5– 6·5	12·0–14·0	5–10	5·0– 6·0	20·0–21·0	50–60	4·5	4·5	5·0–6·0	1·0–2·0	ZT1 Annealed
TZ6 Heat Treated	—	9·5–11·0	17·0–19·5	5–15	—	—	65–75	5·3	5·0	6·0–8·0	1·0–2·0	TZ6 Heat Treated

Commercial Casting Alloy

Elektron "C" alloy (8·0% aluminium—0·5% zinc—0·3% manganese) possesses mechanical properties similar to those of D.T.D. 424 aluminium-base alloy; it is competitive in price on a volumetric basis, and is, therefore, used where the one-third reduction in weight and superlative machinability are of importance to the designer and production engineer.

Its largest single usage in this country is still for the transmission casing in the well-known Ferguson tractor. The automotive industry is, in fact, the largest consumer of castings in this alloy—e.g. gearbox and worm gear casings, miscellaneous engine components, etc.—and it is of interest to note that in Germany output of magnesium castings in a similar alloy for the Volkswagen car now promise to rival the Ferguson application in quantity.

Another growing use of Elektron "C" alloy is for gravity die cast pallets used in the production of Marley flooring and roofing tiles. Here the advantage, in addition to lightness, is the fact that the "mix" does not stick to magnesium. Base plates and other "C" castings for machinery to be installed in multi-storey buildings are extensively used to reduce floor loadings.

Expansion of application can be reported in the textile machinery industry, and Fig. 1 shows a new design of high-speed beam for a warp beaming machine. Both the barrel and flanges are in cast "C" alloy, and are designed to withstand the high stresses produced by the thrust and pressure of the yarn both in running at over 1,000 r.p.m., and in almost instantaneous braking from this speed to rest.

Primary Casting Alloys

Reference has been made to the British lead in alloy development. In the last review in this journal, only veiled reference could be made to two new alloys "A" and "B," which were emerging from the Metallurgical Research Department of the author's company. Their compositions and mechanical properties have now been announced,[3] and some of the underlying research work described in detail.[4]

ZT1 Alloy

This is a new casting alloy for service at temperatures up to 350° C., and its inception greatly extends the range of application of magnesium in jet and propeller turbine engines, since the now well-known alloys MCZ and ZRE1 have a practical maximum of 250° C. The composition of ZT1 is magnesium with 3·0% thorium, 2·2% zinc and 0·7% zirconium, and, as shown in Table I, its room temperature tensile and fatigue properties are also an improvement over those for the older materials. Foundry tests have shown it to possess good castability, to be completely free from microporosity (with resulting pressure tightness), and to be exempt from such troubles as cracking or hot tearing. Also it is readily argonarc weldable, so that castings suffering from minor defects or small errors in machining can readily be salvaged. The creep properties of ZT1 are outstanding (Table II and Figs. 2–4), and it is confidently expected that the results from castings now in experimental engine service will lead to wide application of the material.

Considerable purely metallurgical interest attaches to the development of this alloy. Sauerwald[5] first drew

TABLE II.—PROPERTIES OF ZRE1 AND ZT1 ALLOYS AT ELEVATED TEMPERATURES

Alloy	Test Temperature °C.	0·1% Proof Stress tons/sq. in.	Ultimate Stress tons/sq. in.	Elongation % on 2 in.	Test Temperature °C.	Time hr.	Stresses (tons/sq. in.) to produce Creep Strains of: 0·1%	0·2%	0·5%
ZRE1	20	5·5	10·8	5	200	300	4·10	—	—
	100	4·5	10·2	12		500	3·45	—	—
	150	4·1	9·4	17·5	250	100	1·50	1·83	—
	200	4·0	8·4	29·5		300	1·30	1·63	1·92
	250	3·9	7·2	41·5		500	1·15	1·48	1·90
	275	3·2	6·3	42	315	100	0·35	—	—
	300	2·7	5·5	50		300	0·29	0·40	—
	325	2·1	4·7	71		500	0·25	0·38	—
	350	1·6	3·6	97·5					
ZT1	20	6·0	14·0	8	300	10	3·00	3·65	3·95
	275	3·2	5·3	52		100	2·10	2·60	3·25
	300	3·0	4·8	45	325	10	2·35	2·85	3·30
	325	2·8	4·4	45·5		100	1·30	1·75	2·30
	350	2·7	4·3	37		300	1·05	1·35	1·65
	375	—	4·0	32·5	350	10	1·58	1·85	—
	400	—	3·9	42		100	0·95	1·20	1·40
						300	0·70	0·80	1·10
						500	0·60	0·77	0·98

Tensile Properties.—Tests on machined bars after 1 hr. at temperature. *Proof stress* determinations made with extensometer of sensitivity 1×10^{-6}, loads of 0·1 ton/sq. in. being applied at 30-sec. intervals.

attention to the beneficial effects of thorium in endowing magnesium alloys with improved creep resistance, and when this worker's results had been confirmed a systematic programme was put in hand to determine the optimum composition, with particular reference to the effect of zinc additions. It was soon found that this latter factor was of prime importance, and it was finally determined that in the magnesium-thorium-zinc-zirconium system the thorium/zinc compositional ratio was of vital significance (Fig. 5). It was found possible to correlate the type of microstructure and, in particular, the appearance of the grain boundary phase with the thorium/zinc ratio. With ratios below about 0·5, only a tortuous blue phase (Fig. 6) is present, but above about 1·4, only a brown acicular phase (Fig. 7) appears. Optimum creep resistance is, of course, associated with a preponderance of the brown phase.

It was the early discovery of these points which placed the English workers in a leading position in the thorium alloy field, but tribute must also be paid to valuable American research.[6, 7, 8]

It was from the first realised that only long-term creep tests could show the whole picture, and from the overall results the creep curves shown in Fig. 8 were plotted.

Elektron TZ6 Alloy

This alloy, containing 5·8% zinc, 1·8% thorium and 0·7% zirconium, emerged as a "bonus" from the research aimed at the development of a purely high-temperature alloy, because, whilst having very respectable creep properties up to about 250° C., TZ6 proved to have room temperature tensile properties considerably in advance of those of materials previously known, e.g. Z5Z (Table I). Moreover, it was found to be even freer from microporosity than Z5Z, and to be argonarc weldable.

Foundry development of the alloy is in progress, and it is expected to be adopted for especially critical structural applications in aircraft.

ZRE1, MCZ, Z5Z and RZ5 Alloys

These alloys have now become well known, and are widely used in the aircraft industry. Indeed, as shown by the curves in Fig. 9, they are rapidly replacing the older materials A8 and AZ91, containing aluminium and zinc, for aircraft and similar purposes.

ZRE1 and MCZ are mainly used for jet and propeller turbine engine castings, where, quite apart from creep resistance, their excellent founding characteristics are of great value to the designer in permitting complexity of the component. However, the pressure tightness of the alloys has also led to their use in many cases for room temperature service, e.g. in hydraulic accessories. For example, ZRE1 has been tested entirely satisfactorily up to 4,000 lb./sq. in internal pressure.

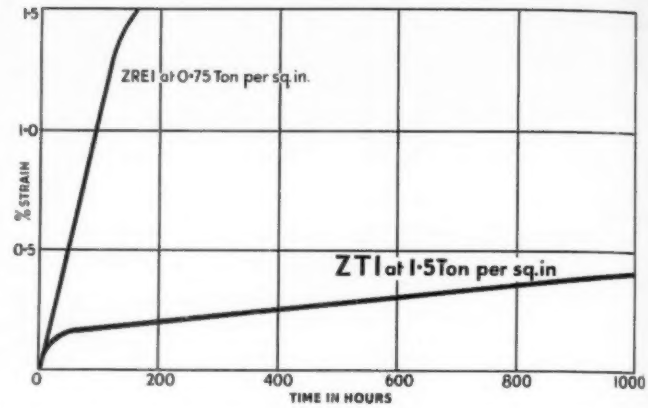

Fig. 2.—Creep curves for ZT1 and ZRE1 at 315° C—ZT1 stress, 1·5 tons/sq. in.; ZRE1 stress 0·75 tons/sq. in.

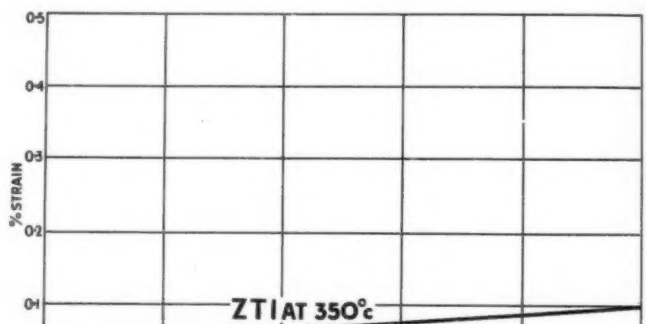

Fig. 3.—Creep curves for ZT1 and ZRE1 at 0·5 tons/sq. in.—ZT1 test temperature, 350° C.; ZRE1 test temperature, 250° C.

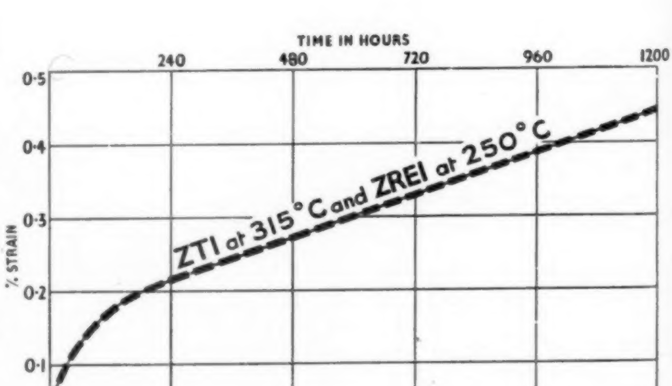

Fig. 4.—Comparison of creep of ZRE1 at 250° C. (full line)and ZT1 at 315° C. (broken line), both alloys tested at a stress of 1·5 tons/sq. in.

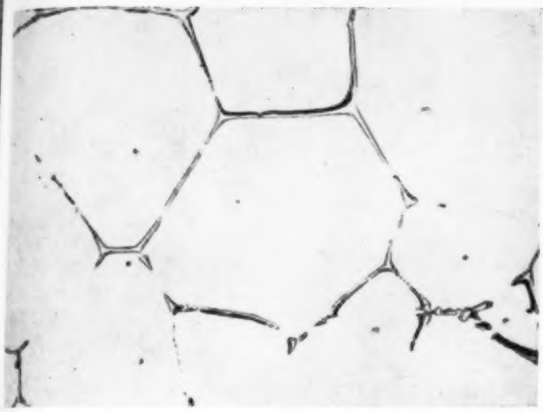

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Fig. 6.—Typical structure of Mg-Th-Zn-Zr alloy showing blue tortuous phase. × 1000.

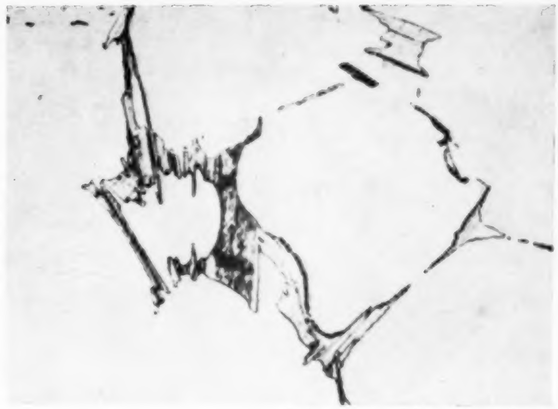

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Fig. 7.—Typical structure of Mg-Th-Zn-Zr alloy showing brown acicular phase. × 1000.

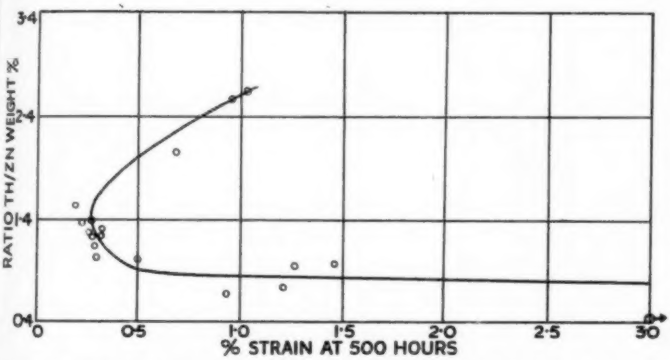


Fig. 5.—Effect of Th/Zn ratio on creep resistance of Mg-Th-Zn-Zr alloys at 1·5 tons/sq. in. and 315° C.

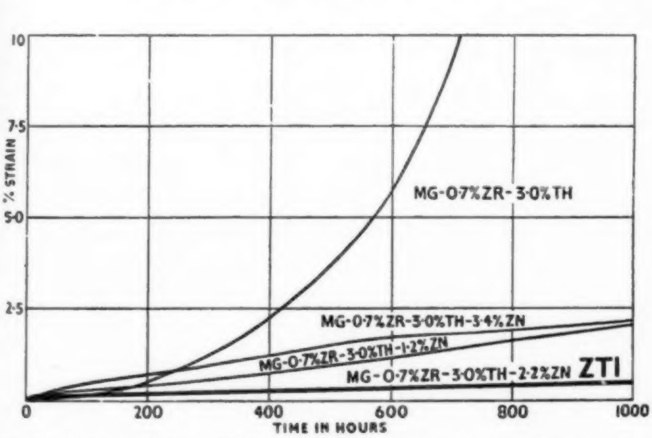


Fig. 8.—Effect of zinc additions on the creep resistance of magnesium —0·7% zirconium—3% thorium alloy. Temperature, 315° C; stress, 1·5 tons/sq. in.

Z5Z and RZ5 are used mainly in airframes, where high proof stress is at a premium. Very large Z5Z undercarriage castings made by Sterling Metals, Ltd. for one of Britain's newest bombers have already been widely publicised, particular attention having been drawn to the uniformity of properties in comprehensive cut-up tests. A more recent application is the De Havilland "Sea Venom" canopy assembly produced by J. Stone & Co. (Charlton), Ltd. in RZ5 alloy, which was itself developed in their Metallurgical Research Laboratory. As will be seen from Fig 10, this canopy is a most elegant example of the founders' art.

It is built up from the six castings indicated in the illustration, and, since it is impracticable to machine their aerodynamic contours, they have to be cast to a high order of accuracy, the average scurfing allowance being only 0·030 in. All are subjected to 100% radiographic examination, upwards of 75 radiographs being used for each assembly, which has overall dimensions of 8 ft. 6 in. length, 3 ft. 6 in. maximum width, and 1 ft. 8 in. maximum height. It is interesting to note that the hatch has to be capable of being jettisoned in emergency by means of a cartridge: it has in fact to be able to withstand this under a 10 ft. head of water. RZ5 alloy was chosen for this structure because of its excellent castability and freedom from microporosity and contraction cracking troubles, and also because its high proof stress is developed by only a low temperature heat-treatment. Reference should be made to a recent article by Millward[9] for further information on these alloys.

Wrought Alloys

After years of hesitation, the British aircraft industry is now commencing to use wrought magnesium alloys in increasing quantities, but not yet to the extent applying in America, where such use has been encouraged by both Government directive and substantially lower prices than obtain here. Security restrictions preclude description of a number of these new applications, but it may be said that one of our newest bombers has large areas of its wing skinned in ZW3 (Table III) and other magnesium alloys. The Westland-Sikorski S55 helicopter has its

TABLE III.—PROPERTIES OF ZIRCONIUM-CONTAINING WROUGHT ALLOYS AT NORMAL TEMPERATURE

Alloy		Specification	Tensile Properties			Compressive Properties		Vickers Hardness
			0·1% Proof Stress tons/sq. in.	Ultimate Stress tons/sq. in.	Elongation % on 2 in.	0·1% Proof Stress tons/sq. in.	Ultimate Stress tons/sq. in.	
ZW3	Sheet 18 S.W.G. and thicker ..	D.T.D. 626	11·0–14·0	17·0–20·0	8–18(1)	9·0–10·5	—	60–70
	Sheet thinner than 18 S.W.G. ..	D.T.D. 626	10·0–12·0	16·0–18·0	(1)	N.D.	—	60–70
	Solid extrusions greater than 0·375 in.	D.T.D. 622	14·0–17·0	20·0–23·0	10–25	12·0–15·0	25·0–30·0	65–75
	Solid extrusions 0·375 in. and thinner	D.T.D. 622	12·0–15·0	18·0–21·0	10–15	N.D.	—	65–75
	Press forgings	D.T.D. 619	13·0–15·0	19·0–22·0	8–14	10·0–13·0	24·0–28·0	60–80
	Impact forgings	D.T.D. 729	11·0–14·0	17·0–20·0	8–12	9·0–12·0	21·0–26·0	60–80
ZW1	Sheet 18 S.W.G. and thicker ..	D.T.D. 000 (Draft M.34)	10·0–12·0	16·0–18·0	8–18(1)	N.D.	—	N.D.
	Sheet thinner than 18 S.W.G. ..	D.T.D. 000 (Draft M.34)	9·0–11·0	15·0–17·0	(1)	N.D.	—	N.D.
	Solid extrusions greater than 0·375 in. and up to 2 in. ..	D.T.D. 000 (Draft M.35)	11·0–14·0	17·0–20·0	10–20	N.D.	N.D.	N.D.
	Solid extrusions 0·375 in. and thinner	D.T.D. 000 (Draft M.35)	10·0–12·0	16·0–18·0	10–15	N.D.	—	N.D.
	Tube	D.T.D. 000 (Draft M.36)	11·0–14·0(2)	16·0–20·0	4–15	N.D.	—	N.D.
ZW6(3)	Extrusions: as extruded	D.T.D. 000 (Draft M.37)	12·0	18·0	10	N.D.	N.D.	N.D.
	Extruded and heat-treated ..	D.T.D. 000 (Draft M.37)	15·0	21·0	10	N.D.	N.D.	N.D.

(1) 12 S.W.G. and thinner: 180° cold bend of 8T.
(2) 0·2% proof stress.
(3) Properties are proposed specification minima.
ND = Not determined.

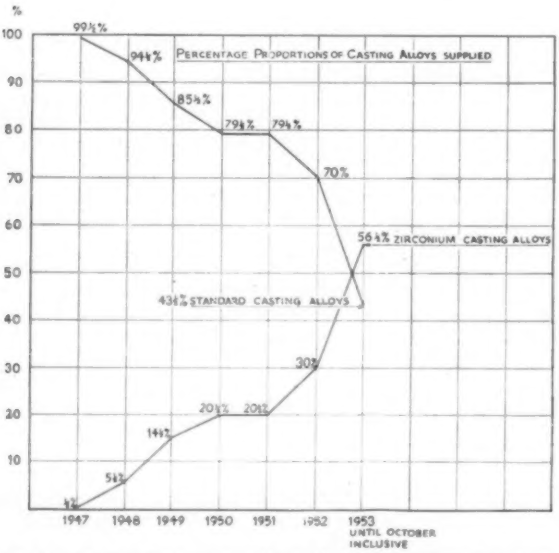


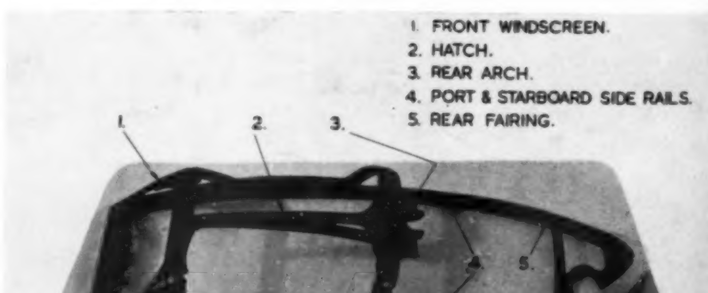
Fig. 9.—Percentage proportions of aircraft quality casting alloys supplied by M.E.L. from January, 1947, to October, 1953, inclusive.

entire fuselage skinned in ZW3, with the exception of one very thin gauge fairing which is made in an older magnesium alloy. The weight of magnesium sheet in the fuselage is, in fact, 21·2% of the structure weight.

The window and escape hatch frames, the freight door frame and a number of internal secondary structures for the Bristol "Britannia" airliner are constructed in ZW1 alloy (Table III). These assemblies (Fig. 11) are made from argonarc welded sheet, extruded sections and tube, hot forming being used where necessary. A recent application outside the aircraft field is the adoption by Pye, Ltd., of Elektron pressings for the structures of their television cameras (Fig. 12).

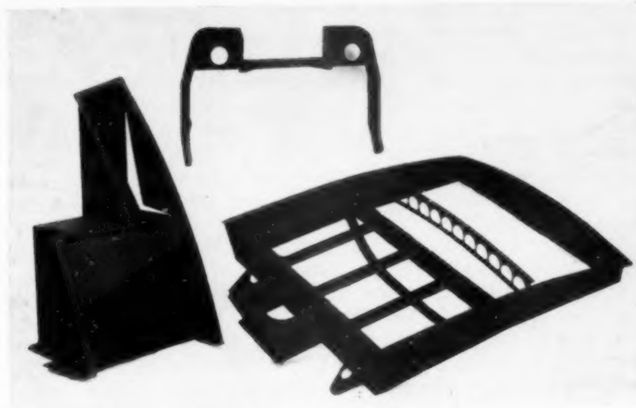
Although the thorium-containing alloys can be used for extrusions of higher properties, it cannot be said that any important advances in wrought alloy technology have been made in the last two years. It will be remembered that alloys based on the magnesium-lithium system, which, when containing about 11% of lithium, become body centered cubic instead of close packed hexagonal in lattice structure, have shown great promise in both cold workability and equality of tensile and compressive properties. A very considerable amount of research has been carried out on these materials, but, unfortunately, quite apart from the high cost of lithium of requisite purity, problems of instability, creep at tropical temperatures and poor corrosion resistance have prevented their exploitation. Research continues, mainly on fundamental constitutional lines.

Another approach[10] to the development of wrought alloys of improved compressive properties is that in which extrusions are made from compacts of heavily cored alloy powder, itself manufactured by a special process. Investigations are also proceeding on the magnesium equivalent of sintered aluminium powder.



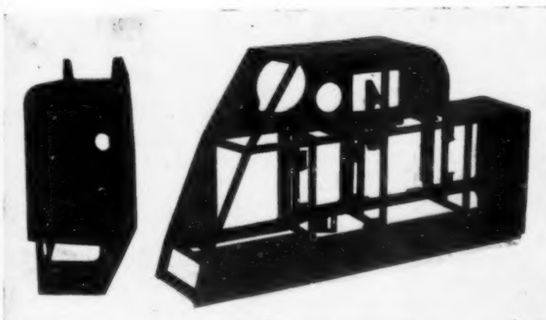
Courtesy of De Havilland Aircraft Co., Ltd. and J. Stone & Co. (Charlton), Ltd.

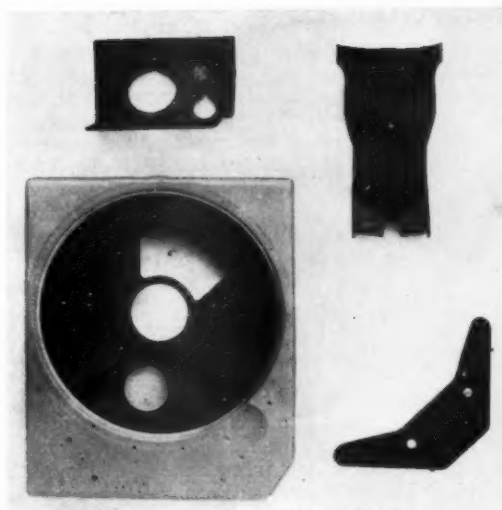
Fig. 10.—Assembly of De Havilland "Sea Venom" canopy castings in RZ5 alloy.

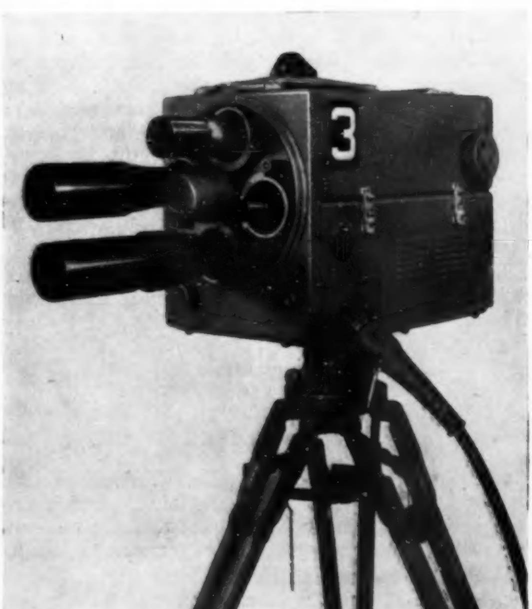


Courtesy of The Bristol Aeroplane Co., Ltd. and Birmetals, Ltd.

Fig. 11.—Some Bristol "Britannia" components in argonarc welded ZW1 sheet and extrusions.

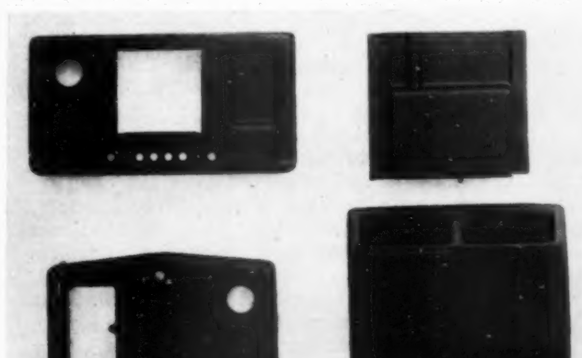






Courtesy of Pye, Ltd.

Fig. 12.—Pye television camera and some of the numerous Elektron sheet pressings used in its construction.



Surface Protection

Renewed attention is at present being paid to the great desirability, wherever possible, of avoiding shot blasting as a fettling process for magnesium alloy castings, or at least of removing the resulting iron contamination in the many cases where shot blasting is essential. It is, of course, well known that surface contamination with iron leads to a very large increase in corrosion rate (even a hundredfold), and shot blasting is, in fact, prohibited in D.T.D. 911A for unmachined high purity A8 alloy. M.E.L. has at an advanced stage of development a process which may prove of considerable significance in this matter. The magnesium casting is anodised in ammonium fluoride solution, and the process may be employed either to fettle the rough casting (removal of sand particles, etc.) or, at least, to remove iron contamination from a shot-blasted casting. Also, under suitable conditions of voltage and current density, a fairly hard protective film can be produced.

In the U.S.A., the "H.A.E." process[11,12,13] has evoked substantial interest. Full details of bath composition, etc., have not yet been released, but it is an anodising treatment which produces a very hard and abrasion-resistant brown film which, especially when sealed with wax or like substance, has considerable protective value. Although the film suffers from a certain brittleness and tendency to spalling under deformation, this process may well prove to be a significant development.

Another new process has recently been announced by the Dow Chemical Company as their "No. 17" treatment. Here again, details have not been released, but the treatment is believed to be very satisfactory in protective value and to represent a real advance.

Mention should also be made of epoxy stoving resins, which have been found in recent years to be very suitable as paints for magnesium alloys, to which they show great adhesion, as well as being extremely flexible and impermeable to water.

Cathodic Protection

The science of cathodic protection progresses steadily, and there can be no doubt that requirements of magnesium alloy anodes for the protection of steel structures in sea water (e.g. ships, piling, dockgates, buoys) and on land (pipe lines, cables, etc.), will in the not too distant future absorb large tonnages of the metal. Over the past few years, there have been a number of refinements in the design of magnesium anodes for special purposes and, in particular, devices have been introduced to ensure a high initial current output producing rapid polarisation of the steel surface.

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Society of Engineers Centenary Celebrations

THE Society of Engineers is celebrating its centenary in 1954. The only professional society in Britain covering all branches of engineering, it was founded in London in 1854 as the Putney Club, for the reunion of engineers who had been educated at Putney College. It became the Society of Engineers in 1857. In 1910 it was amalgamated with the Civil and Mechanical Engineers' Society, which had been formed in 1859, and since then it has been known as the Society of Engineers (Incorporated). It is the third oldest engineering society in Britain. Its President-Elect for Centenary Year is Mr. W. R. Howard, an authority on ferro-concrete engineering, who has received three French awards for his work in the international field. He has been a member of the Society since 1917, a Fellow since 1946, and Hon. Treasurer since 1947.

A centenary Committee is organising a comprehensive programme of events to mark the Society's 100 years' service to civilisation. The celebrations will open on May 4th with a conversazione at the Science Museum, South Kensington. On Wednesday, May 5th, a business session will be devoted to the presentation of papers dealing with 100 years' progress of civil, mechanical, electrical and aeronautical engineering. This will be at the Geological Society's apartments at Burlington House, Piccadilly, where the ordinary meetings of the Society are held. On May 6th there will be a day trip on the River Thames to visit the Lafarge Aluminous Cement Company's works at West Thurrock, Essex. The climax to the celebrations will be the centenary banquet in the historic Fishmonger's Hall, beside London Bridge and close to an early meeting place of the Society.

Scottish members will hold their own centenary celebrations on May 15th with a banquet at the headquarters of the Royal Society of Edinburgh. Mr. Alexander Mason is Chairman of the Edinburgh and East of Scotland Branch. The Society's members, who hold leading positions throughout the world, are strong in Australia, and separate celebrations will be held there. The Divisional President of the Australian Division is Emeritus Professor Sir Henry Barraclough, K.B.E., who was Dean of the Faculty of Engineering of Sydney University.

Correction

FRACTOGRAPHIC PATTERNS OF SEGREGATION

WE regret that the article by Dr. C. A. Zapffe on "Fractographic Patterns of Segregation," which appeared in the September issue of METALLURGIA, contained the following typographical errors.

The phase referred to in line 3 of the caption to Fig. 1 on p. 130 should be α not β, whilst the phase referred to on lines 19 and 32 of p. 131 should be α not γ.

Copper and Copper Alloys

A Survey of Technical Progress During 1953

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such subjects as raw material resources, extraction, fabrication finishing and properties.

In spite of the restoration of the free market and re-opening of the Exchange, the year now closing will hardly be regarded by those concerned with copper as among the more prosperous which the industry has seen. Nevertheless, there has been no lack of activity in scientific and technological development, to judge from the abundance of informative literature which has appeared. In a brief review of this nature, it is impossible to do more than to outline a selection of the items which appear to be of especial interest and value, and to mention certain others which the reader may like to consult for himself.

The Production of Copper

If press reports are to be believed, it appears that an exceedingly promising new source of supply of copper and nickel is being developed in Canada, at a site known as the Gordon-Werner-Rex Lake property in Manitoba.[1] The deposit stretches for seventeen miles, and the Quebec Nickel Corporation, Ltd. have announced that shaft-sinking will start immediately. Another large deposit of low-grade copper ore, averaging less than 1% copper, is to be developed by the Kennecott Copper Corporation in Nevada by open pit methods.[2] In Europe, it has been reported that the Swedish Boliden Mining Company has asked the Norwegian Government for a long-term concession to mine copper in a region covering 400 square miles around Kaotokieno, in the inner highlands of Finnmark, Northern Norway.[3] Some particulars have been published concerning the established Murgal copper mine in Turkey,[4] while, according to Slechten and Bruce,[5] the installation of a new acid leaching section has increased the recovery of copper from Cyprus ores by 10%. It would appear that similar methods are in use at the Greater Butte concentrator of the Anaconda Mining Company,[6] where a combination of leaching with flotation has enabled much low-grade material, once considered as waste, to be exploited. Underground leaching operations are being commenced in the Bunker Hill district of Arizona,[7] while Ramsey[8] has reviewed mining and concentration practice at White Pine.

In the preface to his able book on the physical chemistry of copper smelting, Ruddle[9] suggests that slow progress has been made in the development of improved or new principles of copper smelting during the past half century. It seems doubtful whether the indictment is entirely merited. For example, the new process of flash smelting, which requires no fuel other than the sulphur in the concentrate, is undoubtedly very promising, so much so, in fact, that a second furnace is to be set up at Copper Cliff[10] to operate on copper, and it is proposed to extend the technique to the treatment of nickel concentrates. Further, the entirely new process of ammoniacal leaching followed by precipitation with hydrogen under pressure, developed by the Sherritt Gordon interests in collaboration with the Chemical Construction Company, is attracting considerable attention, and has even been hailed as something of a metallurgical revolution.[10-19] It appears, however, that the method is not as yet being applied to the production of copper powder in bulk, but rather to that of nickel, though the technique is said to operate upon copper. A somewhat similar ammoniacal leaching method has been patented in this country by Tobelmann,[20] while Rusher and Blum[21] have suggested comparable means of precipitating sponge-like copper from waste pickling sludge.

On hydrometallurgy generally, the new book by Van Arsdale[22] is a veritable mine of information, and several interesting descriptions of current practice in copper smelting have recently appeared. A condensed version[23] of an earlier article[24] on Chuquicamata makes excellent reading, as also does a comparable description[25] of the Earfield plant of the American Smelting and Refining Company. The arc furnace equipment at the Kennecott Refinery at Garfield, Utah, is the subject of a publication by Shaw and Whitton.[26] This plant, said to be the only one of its kind in the United States, is very similar to, and indeed is modelled upon, that which has been in use for many years by the International Nickel Company at Copper Cliff. Design features and operating methods at the new Ajo smelter of the Phelps Dodge Corporation are described by Byrkit,[27] who emphasises the relatively high smelting rate in the single furnace available. Alston and Winkel[28] claim that the anode output at Garfield, namely 23,000 tons per month, is greater than that of any other single plant in the world, while Weis, Busch and Spaulding[29] give a detailed account of the recent complete rehabilitation of the electrolytic refinery of the American Smelting and Refining Company at Porth Amboy.

Turning from America to Africa, Talbot[30] has described the recently installed leaching plant at Nchanga, where agitation leaching of mixed oxide and sulphide ore is in operation, while Lyons[31] gives an account of the Lubumbashi smelter at Elisabethville. This is one of the few plants where blast-furnace smelting is still practised. A note[32] indicates that the copper outputs of the new Bancroft and Chibulma projects in Northern

Rhodesia are expected to reach 48,000 tons and 16,000 tons per annum respectively by 1956.

In Japan, a new method has been developed for the recovery of copper, and also of iron and nickel, contained in the sinter which remains from the production of sulphur from cupriferous pyrrhotite.[33] According to a recent British Patent,[34] it is possible to recover copper, nickel and cobalt from converter slag by melting in the presence of a reducing agent, such as an alloy of silicon and iron, or of silicon, iron and aluminium. It is difficult to appreciate the advantages of such a process, at least in respect of copper smelting, over the normal practice of returning the converter slag to the reverberatory furnace, though Ellwood and Henderson[35] have pointed out that converter slag is the source of about 13% of the magnetite formed in the reverberatory. These authors also mention the use of reducing agents to decrease the proportion of magnetite in converter slag.

Dannatt and Richardson[36] have outlined projected research on extraction metallurgy under the Nuffield Research Group at the Royal School of Mines. The present programme consists of ten items, five of which are directly concerned with copper.

Foundry Practice

The Institute of Metals has inaugurated a series of annual symposia on the control of quality in the production of wrought non-ferrous metals and alloys, and the first of these was concerned with the control of quality in melting and casting. Of the six papers presented, two dealt specifically with copper-base materials, while a third served as a general introduction to the whole series. This latter, by Singer,[37] gives a clear outline of the basic principles of technical control, reviewing automatic control as well as statistical methods and others involving a human operator. He emphasises that, in normal circumstances, a degree of quality somewhat below perfection is the most economical to produce, and outlines principles for ascertaining and maintaining this optimum quality.

Both of the other papers concerned with copper-base materials in the symposium are essentially practical in outlook, that by Cook and Cowley[38] dealing with brass and the allied alloys, and that by Sykes[39] with copper and alloys of high conductivity. The papers are alike in recording so great a volume of practical detail and so many valuable recommendations that they are almost impossible to summarise. Comparable with these papers is a series of articles by Reid[40] on the founding of high-tensile brass and aluminium bronze. This author clearly draws on extensive practical experience, on the basis of which he is able to give much detailed advice.

A Sub-Committee of the Institute of British Foundrymen has recently given careful attention to the economic utilisation of copper-base alloys, and has issued a thoughtful and illuminating report.[41] It recommends that, in the interests of economy, the sections of castings should be kept to a minimum, relying, where possible, on materials of relatively high strength, while keeping factors of safety to the lowest practicable levels, and that, for efficiency in handling ingots and scrap in the foundry, the number of specifications in current use should be reduced.

The important subject of the incidence and effects of internal stresses in castings has recently exercised a Technical Committee of the Institute of British Foundrymen.[42] It was found that temperature gradients are a greater potential source of internal stress in castings than is constraint by the moulds and cores. Stresses arising from constraint by the sand tend to disappear when the casting is removed from the mould, whereas stresses caused by temperature gradients may remain locked in the metal. On the other hand, at temperatures approaching the melting point, constraint by the mould may well lead to transitory stresses which are relieved by hot tearing. Such conclusions accord with recent experimental work by Parkins and Cowan,[43, 44] Middleton,[45] and Pellini.[46]

In an address on runners and risers for non-ferrous castings, Ruddle[47] emphasises the desirability of ensuring, as far as possible, directional solidification. For this reason, top pouring is generally advisable, and feeders should be located near the thickest parts of the casting. Feeding can be improved by the use of blind feeders, or by covering open feeders with sand after they have been filled with metal. Insulating and exothermic sleeves around the feeders are valuable but are not invariably economic. Downgates should taper gently so that they can be kept filled without inducing turbulence, and the cross runner should have a sectional area about twice that of the downgate, to reduce the velocity of the metal as it enters the mould cavity. A well-illustrated article on the principles underlying the design and positioning of risers has been published by Walton,[48] while Caine[49] reviews the advantages and disadvantages of necked-down risers. The theme of this breezy article is that, intelligently used, the necked-down riser can generally be made to function well, and to effect considerable saving in fettling costs.

The shell moulding process is undoubtedly evoking considerable interest in this country.[50, 51] At least two automatic machines were displayed at the British Industries Fair, while a number of chemical manufacturers are making resins for the purpose. Another comparatively recent development is the use of semi-permanent refractory moulds bonded with ethyl silicate.[52, 53, 54] These impart to the castings a smoothness of surface and dimensional accuracy comparable with die castings, while runs of several hundred castings can be achieved without difficulty.

Discussing the casting of phosphor bronze in moulds made from materials having different rates of heat extraction, Pell-Walpole[55] finds that the rate of pouring has an appreciable effect on the extent of shrinkage porosity when the mould material has a high chilling power. On the other hand, pouring temperature becomes a factor of primary importance in the case of sand castings. Taylor, Stokowiec and Jackson[56] likewise found the control of pouring temperature and the rate of cooling to be important factors in the production of sound castings in nickel bronze by centrifugal methods.

Aluminium has long been recognised as a detrimental impurity in cast bronzes and gunmetals. Larsson[57] has confirmed that as little as 0·01% of aluminium is harmful to the pressure tightness of castings in leaded gunmetal and brass, and has shown how aluminium can be removed by fluxing with mixtures of fluorides with carbonates and sulphates under oxidising conditions. Silicon, though less harmful than aluminium, can be eliminated with the same fluxes. Blanc and Thomas[58] describe the use of fluxes based on manganese dioxide and potassium nitrate for the removal of aluminium.

The pressure tightness of leaded gunmetals has also been studied by Kura and Eastwood,[59, 60] who found that moulds made from calcined clay gave better results than those from normal sands. According to tests by Bunch and Dalbey,[61] it is easier to produce pressure-tight castings from aluminium bronze than from gunmetal, provided that the metal is run without turbulence.

Up to the present, comparatively little has been published on the grain refinement of cast copper-base alloys, although research on the subject is known to be in progress. An investigation by Dennison and Tull[62] has shown that the grain size of aluminium bronzes, particularly those with sufficient aluminium to solidify as *beta*, can be greatly refined by the addition of a small quantity of boron. It is suggested that the inoculating substance is boron carbide. The grain refinement is associated with increased tensile strength and elongation.

An interesting paper by Brown[63] suggests that the formation of superficial cracks on the faces of dies for the pressure die casting of brass is attributable to the formation of a brittle layer of an iron-zinc compound, rather than to the direct effects of thermal shock and fatigue. Brown points out that steel dies used in the glass bottle industry do not develop cracks, though they are subjected to thermal stresses in excess of those occurring in brass casting dies. An extensive review of casting in permanent moulds has been published by Carr-Harris.[64]

A few ideas which seem worthy of attention are the use of hot core boxes to dispense with drying ovens;[65] plating the surface of investment patterns with a metal of high melting point, which remains to line the interior of the mould cavity when the pattern is melted out,[66] and a modification of the Junghaus continuous casting machine to permit of slow cooling and improved feeding.[67]

No less than five new books on foundry subjects embracing copper-base materials have appeared in recent months, one in this country,[68] three in America,[69, 70, 71] and the fifth in France.[72] The latter, an album of casting defects, is claimed to be the most comprehensive of its kind so far published. A description of the methods used in the industrial production of non-ferrous ingots for casting is to be welcomed.[73]

Fabrication

Although it made no direct reference to copper, the recent conference on the cold extrusion of steel organised by the Sheet and Strip Metal Users' Technical Association deserves special mention. From the substance of the papers presented[74-80] it is apparent that equipment, including die materials, and techniques are now available for the cold extrusion of steels by processes similar to those already well established for the softer alloys based on lead, tin, zinc and aluminium in the manufacture of collapsible containers and similar articles. There can be little doubt, therefore, that copper-base alloys, forming an intermediate group in respect of resistance to deformation, could readily be extruded at ordinary temperatures if so desired. The process is quick and gives a good surface finish without subsequent pickling, while dimensional accuracy can be held with considerable precision. Moreover, the extruded material remains in the strong, cold worked condition, the degree of cold work being more uniform than in deep drawing. A further review of applications to steel has been contributed by Sieber,[81] while Chase[82] describes a somewhat similar method of producing copper commutator segments in large quantities by cold heading. In a new technique of cold impacting, two hammers are driven together from opposite sides of the specimen by compressed air.[83] Advantages are claimed over ordinary presswork operations in which only one of the compressing members moves.

Perry[84] has outlined the Ugine-Sejournet technique of using glass as a lubricant in the hot extrusion of metals. This principle was developed mainly to facilitate the extrusion of steels. Nevertheless, the possibilities of the process for copper and its alloys merit consideration, for tests mentioned by Perry indicate that it gives satisfactory results with such materials. It will be remembered that in 1948 Blazey and others presented to the Institute of Metals an illuminating paper on the flow of metal in tube extrusion.[85] This has now been followed by a further publication[86] recapitulating and extending the work, including the use of molten glass as a lubricant. The question of rotary piercing is also considered. According to Hill[87] a method of "rotary extrusion" permits the production of tubes with integral helical fins in copper and copper alloys, as well as in aluminium, steel and clad metals. Integrally finned tubes made by a method akin to thread rolling are by no means new, but their fabrication by hot extrusion appears to be a novel development. Tube-producing practice in general has been covered by a symposium report published by the American Institute of Mining and Metallurgical Engineers.[88] It contains a contribution by Bassett on the production of tube in copper and copper-base alloys, giving a useful picture of the methods employed in the United States. A reprint of the well-known book by Pearson[89] on the extrusion of metals is to be welcomed, certain revisions having been made to the text. It may be added that die steels for the extrusion of non-ferrous materials formed the subject of an open discussion organised in Birmingham by the Institute of Metals,[90] while it is understood that the Nimonic alloys have given promising results as extrusion dies for copper.

Concerning the manufacture of copper wire, an imaginative article[91] has opened the question of adopting much larger wire bars than those in present-day use, with the introduction of continuous rolling as in the cases of steel and aluminium. The operation of the normal looping mill for the production of wire rod has been described in detail by Mort,[90] who gives much information on the calculations involved in designing the various passes. Lubricants for wire drawing, including those suitable for copper, are dealt with in papers by Williams[93] and McAulay,[94] while an improved type of planing die for copper wire has been developed and patented.[95]

A new series of articles on the rolling of metals and alloys by Larke[96] promise to be of much interest and value: the early instalments are well written and illustrated. A new type of rolling mill, based on a Sendzimir patent,[97] with small diameter-work rolls moving round larger backing rolls in a planetary manner, has recently been put into operation for the hot rolling of steel.[98, 99] It is claimed that costs are considerably less than those of conventional hot rolling mills.

Several years ago the British Non-Ferrous Metals Research Association issued to members a confidential document on the bright annealing of copper and copper alloys: this has now been revised and published,[100] and

the paper is among the most authoritative which have appeared on the subject. The application of induction heating to hot forging and similar processes has recently received considerable attention,[101, 102] and a logical outcome is the development of a fully automatic forging machine incorporating this type of heating.[103] Of less specialised scope is a well illustrated description of various modern installations for the heat treatment of ferrous and non-ferrous metals and alloys.[104]

The occasional formation of blisters during the annealing of brass sheet has been traced by Eborall and Swain[105] to hydrogen entrapped in a central unsound region of the cast ingot. It was shown that the blisters could be eliminated by introducing an annealing treatment at a comparatively early stage of rolling.

The techniques used in the manufacture of brass musical instruments, a specialised subject on which little information is available, have been described in some detail.[106] The material is cartridge brass of high quality, annealed as necessary during fabrication. Tubular bends and tapers of intricate shape are made by hydraulic forming in closed dies, and it is interesting to note that the dies themselves are cast in an unusual "white brass" consisting of 84% zinc, 12% copper and 4% aluminium, which can be finished to a high degree of surface perfection.

Finishing and Plating

White brass plating, which is being used, particularly in America, as a substitute for nickel beneath chromium, has been described in more detail than heretofore in papers by Saltonstall.[107, 108] Zinc predominates in the deposited alloy, which tends to be brittle unless careful control of the bath and operating conditions is maintained; moreover, corrosion resistance is not particularly high. Binai[109] has published a method of maintaining the copper content of white brass plating solutions by means of an electrolytic regenerating technique. Richter[110] claims that coatings of "brass" (in reality tin bronze) can be obtained on steel by simple immersion in a solution containing a mixture of tin and copper sulphates, while Strabovska[111] has developed the electrodeposition of brass from an oxalate bath. The coatings are said to have good ductility and adhesion, but control is critical.

A new fast process for the electrotinning of copper wire[112] is said to achieve speeds up to 600 ft./min. on 18 s.w.g. wire, using a tank 20 ft. in length. Operating at 200° F. with a current density of about 560 amp./sq. ft., tin thicknesses of about 0·00002 in. are obtainable at the speed mentioned.

Another interesting development is the manufacture of metallic mesh by electrodeposition[113] in a manner which appears to be essentially different from the technique of electrodepositing metals upon fabric meshes.[114]

Hospadaruk and Winkler[115] have studied the effect of chloride on the electrodeposition of copper from sulphate baths in the presence of arsenic, antimony and bismuth. They found that while chloride tends to decrease polarisation, gelatine has the reverse effect. Experiments by Gauvin and Winkler[116] on the use of bindarine show that it increases the hardness of the deposit, and also the cathode polarisation, but less so than gelatine. Bindarine is a by-product of the sulphite pulp industry, and contains calcium lignosulphonate. References to other work on allied subjects by this group of authors will be found in the papers mentioned.

Heritage and Balmer[117] have reviewed the techniques of metallising glass, ceramics, plastics and similar non-metallic surfaces, while Narcus[118] has patented a process for carrying out such operations, using the fluoborate of the metal, for example copper, to be deposited.

An informative review of the pickling and bright dipping of copper and copper-base alloys has been published by Halls[119] and others of mechanical surface finishing by Colegate,[120] Mable[121] and Sawyer,[122] while Homan[123] states that ultrasonic vibrations have been applied to good effect in the cleaning of metallic articles of intricate shape. According to Kaurat,[124] a bath suitable for the electropolishing of small pressed brass parts consists of a mixture of phosphoric acid, glycerol, ethylene glycol, lactic acid and water, with additions of glutamic acid or monosodium glutamate if a mirror finish is desired.

The recovery of copper from rayon plant wastes by ion exchange, using suitable resins, has been described by Paulson,[125] and Downie[126] suggests that spent copper electrolytes should be enriched and used for the production of copper sulphate.

Properties and Applications

It is well known that the addition of small quantities of elements which enter into solid solution in copper have a marked influence on its rate of recrystallisation and grain growth during annealing. Phillips and Phillips[127] have examined the effects of phosphorus, silver, cadmium, arsenic, tellurium and oxygen in considerable detail. The paper is primarily of theoretical interest, but a number of valuable practical observations also emerged. For example, it was shown that the first small additions of phosphorus retarded recrystallisation much more than either silver, cadmium or arsenic, but larger additions of silver and cadmium produced greater effects than phosphorus. Moreover, unlike previous investigators, Phillips and Phillips found that tellurium tends to accelerate rather than to retard recrystallisation.

Also concerned with the annealing of copper is the work of Houlden and Baker,[128] who found that if the phosphorus content of deoxidised copper falls below about 0·01% there is danger of the breakdown of any slaggy inclusions which it may contain, with the liberation of cuprous oxide. If, then, such material is annealed in an atmosphere containing hydrogen, there is risk of embrittlement by "gassing" similar to that which occurs when tough pitch copper is annealed under such conditions.

From creep-rupture tests in air and *in vacuo* on O.F.H.C. copper, among other materials, Bleakney[129] infers that oxygen-free copper may absorb sufficient oxygen, even at temperatures in the neighbourhood of 400° C., to impair grain boundary cohesion throughout the section of 16 s.w.g. wire. If true, this is a distinctly disturbing conclusion. Kennedy[130] has reported comparative creep tests under continuous and intermittent stresses on high conductivity copper, and has analysed the relationship between the creep strains produced by these two types of loading.

Though discontinuous yielding such as that exhibited by certain steels is comparatively rare in copper-base alloys, Polakowski[131] has found the phenomenon to occur in a phosphor bronze containing 6% of tin, when "strain-aged" at a temperature insufficiently high to cause recrystallisation.

Several newly developed copper-base alloys may be brought to the attention of readers. An article by Hannon[132] describes a precipitation hardening material which is said to combine good mechanical properties with high resistance to stress corrosion. The composition is given as 3–5·5% nickel, 0·7–2% silicon and 0·3–1% iron, the remainder being copper. According to publications by the Battelle Memorial Institute,[133, 134] material containing about 10% nickel with 4% aluminium and 1·5% silicon can be formed readily in the solution-heat-treated condition, and, after precipitation hardening, has properties comparable with those of beryllium copper.

Another proposed substitute for beryllium copper, which attracted considerable attention in the past, is the copper-nickel-manganese type of alloy which can be hardened by "ordering" of the crystal lattice, rather than by precipitation of a second phase from solid solution. While this material has yet to achieve popular acceptance, it is interesting to note that Dahl and Dreyer[135] in Germany, have recently re-examined and confirmed its properties. It is curious that the value of another established heat treatable alloy, chromium copper, seems only recently to have been appreciated in Germany,[136] and that Piwowarski, Patterson and Koper[137] should have reported the well-known fact that additions of nickel confer precipitation hardening properties on tin bronzes and gunmetals.

During the past few months, no less than three papers have been published on the ternary copper-tin-manganese alloys, by Funk and Rowland,[138] Blade and Cuthbertson,[139] and Valentiner,[140] respectively. Such materials include the Heusler alloys, known for their magnetic properties. Funk and Rowland are in substantial agreement with Blade and Cuthbertson in showing that a marked diminution in the solid solubility of tin in copper is brought about by the addition of manganese. The latter authors examined the mechanical properties of the alloys, and found that, while extreme brittleness occurred in some cases, this could be mitigated by controlled cold working and heat treatment. The work of Valentiner included a consideration of the effects of heat treatment on the magnetic properties of the alloys.

A report by the United States Atomic Energy Commission[141] suggests that the commercial possibilities of nickel silvers with relatively high contents of nickel and zinc may perhaps have been overlooked in the past. The report describes tests on the alloy containing 40% copper, 32% nickel and 28% zinc, which was found to have superior corrosion resistance to commercial nickel silvers, combined with higher tensile strength, hardness and elongation. It is suggested that the casting qualities might be further improved by a small addition of tin without detriment to the mechanical properties. Tests by Cuthbertson[142] indicate that tin may also be a useful addition to cupro-nickel for coining and stamping.

Two new alloys allied to the aluminium bronzes have been announced. The first of these[143] consists of copper with aluminium, iron and nickel in varying proportions, together with between 1% and 4% of titanium. Such alloys are claimed to combine good forging properties with high resistance to corrosion, creep and fatigue at temperatures up to between 300° C. and 350° C. The other material[144] is a casting alloy recommended for ships' propellers and similar marine applications. A metallographic study by Gragnani[145] of the heat treatment of a complex aluminium bronze containing iron and nickel is at variance with the recent work of Cook, Fentiman and Davis[146] in suggesting that the structures may be interpreted in terms of the ternary copper-nickel-aluminium diagram, leaving the iron out of consideration.

After studying the effect of impurities on the mechanical properties and machinability of turning brass, Wood[147] found that an increase in the permissible iron content from 0·15% to 0·35% did not seriously impair the machinability of the alloy. He also examined the conditions under which the presence of 0·02% of aluminium may lead to blistering of brass wire.

Though the alloys of copper with titanium have not up to the present proved particularly attractive, Nicolaus[148] has published a detailed review of their properties. Studies of the constitution of the alloys of copper with zirconium,[149] palladium,[150] manganese,[151] indium,[152, 153] indium with silver[154] and germanium with aluminium[155] have appeared. Yoshikazu[156] has examined the effects of heat treatment on the microstructure, electrical resistivity and hardness of tin bronzes, with special reference to the decomposition of the *beta* phase, while Reeve, Bowden and Cuthbertson[157] have published a collection of annotated photographs which they describe as an atlas of tin bronze structures.

Corrosion and Protection

As the result of a review of the available information on the stress corrosion cracking of brass, de Jager[158] recommends the addition of 1·5% of silicon as a protection against stress corrosion cracking, and emphasises that the grain size should be kept small. Bailey[159] has published the results of stress corrosion tests on a range of cast high tensile brasses of *beta* structure, with various contents of aluminium, manganese, iron, tin and nickel. He pronounced aluminium contents exceeding about 2% to be undesirable in cast high tensile *beta* brasses, as they induce a form of latent intercrystalline brittleness which is subject to aggravation by corrosive agencies, such as sodium chloride solution or sea water. He also observed that the co-presence of iron and manganese in *beta* brasses containing aluminium tends to reduce susceptibility to weakness. Experiments directed towards combating the intercrystalline weakness of cast *beta* brasses containing aluminium have led the British Non-Ferrous Metals Research Association to patent the addition of 0·01–0·5% of titanium or zirconium[160] for this purpose. Hannon[161] has examined the relative merits of different metallic coatings as a protection against stress corrosion. He found that coatings containing tin, whether electrodeposited or flowed-on, gave better protection against cracking in mercurous nitrate solution than any other coating tried. Protection against mercury is of much less practical significance than protection against ammonia. Hannon found, however, that electrodeposited tin, like other electrodeposited coatings, was ineffective against ammonia, whereas a flowed-on layer of tin diminished the attack. It should be remembered that the temperature necessary to melt the tin would tend to relieve any internal stresses which might be present, and so to mitigate stress corrosion, quite apart from the effect of the tin as a protective coating. As previously mentioned, a new copper-nickel-silicon alloy containing a critical amount of iron, said to be particularly resistant to stress corrosion, has also been described by Hannon.[132]

Marine engineers may be interested in a brief letter[162] which indicates that the normal polarity between bronze

or gunmetal and steel may become reversed in polluted estuarine waters, leading to unexpected attack upon the copper-base alloys. A report by the International Nickel Company[163] deals, among other matters, with the effect of additions of zinc, iron, manganese, tin, chromium and arsenic on the resistance of 70 : 30 cupro-nickel to marine corrosion. While most of these additions proved to be harmless, or even beneficial, it was found that zinc tended to aggravate pitting in alloys containing iron, and it was consequently recommended that the zinc content of iron-bearing cupro-nickel should be restricted to a maximum of 0·5%. Baker[164] deprecates the practice of allowing stagnant sea water to remain in aluminium brass condenser tubes, especially when these are relatively new. Examining the contamination of boiler feed condensate by copper from the condenser system, Ristroph and Powell[165] found that, at temperatures between about 120° C. and 220° C., Monel, 70 : 30 cupro-nickel and, somewhat surprisingly, arsenical Admiralty brass caused least contamination, while aluminium bronze and aluminium brass were much inferior in this respect. Also concerned with marine corrosion is the work of Richards[166] on the resistance of beryllium copper to sea water and marine atmospheres. He concluded that beryllium copper compares favourably with copper itself under such conditions.

Several years ago Ingleson, Sage and Wilkinson[167] examined the effect of chlorination of drinking water on the corrosion of brass water fittings, and showed that chlorination was not particularly detrimental to cast leaded *alpha* brasses though it tended to increase dezincification in the case of wrought *alpha* + *beta* alloys. More recently, Wormwell and Nurse[168] have reported that the effect of chlorination varies with the type of water. In several waters chlorination had no definite influence ; in some there was a distinct increase, while in others chlorination appeared to reduce corrosion. Wormwell, with Mercer[169] has also shown that a 0·5% aqueous solution of sodium benzoate completely inhibits the corrosion of copper, among other metals, in tap water and dilute chloride solutions at room temperature.

A paper on soil corrosion[170] was included in a symposium organised by the Iron and Steel Institute. Specimens of copper, aluminium and lead were buried at five different sites in salt marsh, London Clay, moist natural clay, Keuper Marl and cinders, respectively. All three metals were corroded by the cinders, but in the other soils copper proved to be far superior to aluminium, and in most cases also to lead. An exhaustive series of experiments by Denison and Romanoff[171] on the corrosion of various low-alloy irons and steels in soil included tests on copper-bearing steels. These, however, did not prove to be particularly satisfactory under the conditions investigated. On the other hand, publications by Copson[172] and by Hudson[173] confirm the beneficial effects of copper on the resistance of steel to atmospheric corrosion, even under abrasion.

Continuing his work on the oxidation of copper at elevated temperatures, Tylecote[174] has studied the range between 200° C. and 800° C. The results appear to justify the conclusion that the rate of oxidation at high temperatures is determined by the outward movement of metal ions through a film consisting essentially of cuprous oxide, while at lower temperatures the controlling factor is the diffusion of both metal and oxygen through the cupric oxide layer. Somewhat similar investigations have been carried out by Carli and Collari[175] and by McKewan and Fassell.[176] Of much practical interest are the tests of Dennison and Preece[177] on the oxidation of binary alloys of copper with beryllium, aluminium, magnesium, silicon and chromium. The effectiveness of these additions in conferring resistance to oxidation at elevated temperatures was found to decrease in the order mentioned, chromium conferring no protection at all.

Hoar and Tucker[178] have carried out numerous tests on the formation of sulphide films on copper in various liquid media containing this element. They point out that such films have practical importance in the colouring of copper-base alloys, in certain metallographic techniques, and in such industrial processes as the bonding of rubber to brass. Both Bollinger[179] and Welsh[180] have also studied the effects of sulphur compounds on copper and brasses, among other alloys, the former being concerned with the amount of water and oxygen which can be tolerated in sulphur dioxide without leading to serious attack on the metal, while the latter concentrated upon the corrosion of gas appliances by hot sulphuric acid condensate.

A novel suggestion for the protection of polished copper and silver surfaces has been proposed by Loiseleur,[181] namely the formation of a monomolecular film of purple of Cassius (a precipitated mixture of tin hydroxide and metallic gold). It is said that only exceedingly minute quantities of the reagents are required to impart almost complete resistance to oxidation and tarnishing by sulphur compounds.

An illuminating paper by May[182] on the mechanism of pitting corrosion deals almost exclusively with this phenomenon in relation to copper. The conditions necessary for the inception and maintenance of pits are described, with particular reference to the circumstances in which the abnormally rapid type of pitting sometimes encountered in practice can occur. The paper is too full of detailed information to be adequately summarised here, but it is commended to the attention of readers who are interested in the subject, especially from the point of view of corrosion testing and research.

Joining

Among the most important contributions to knowledge of the joining of copper and copper-base alloys which have appeared in recent months is a paper by Davis and Taylor[183] on the use of the argon shielded arc. The work covered a considerable range of materials, both as filler rods and parent metals, but techniques were confined to hand operated methods with non-consumable electrodes of thoriated tungsten.

High conductivity tough pitch copper proved comparatively difficult to weld, either autogenously or with a filler rod containing 1% silver, but rods carrying up to 3% silicon gave results which were considered to be satisfactory. Similar remarks apply to phosphorus-deoxidised copper, which could be welded without difficulty, in plates up to ¼ in. in thickness, with filler rods containing between ¼% and 3% silicon. Copper deoxidised with small quantities of manganese or silicon, instead of the more usual phosphorus, could be welded with considerable facility using filler rods of the same composition.

With aluminium bronze, good results were obtained using the A.C. arc with superimposed high voltage, high frequency current. On the other hand D.C. was preferable for phosphor bronze. Welds in this material

tended to be porous, though strength and ductility were satisfactory. Argon arc butt welds could be successfully made on 70 : 30 cupro-nickel, provided that special filler alloys containing small amounts of powerful deoxidants, preferably aluminium, were used, and similar rods gave improved results on the modern marine alloys of copper, nickel and iron. On brass, the use of silicon brass filler rods reduced but did not prevent the volatilisation of zinc, while excellent results were obtained at high speed on silicon bronze.

An important advantage claimed for the argon arc process is the ease with which multi-run welds can be made, while it is suggested that the development of the nitrogen-shielded arc may increase the thickness of copper which can be successfully joined with normal equipment. The application of the process to fillet welds is also briefly described.

In describing the butt welding of copper rods for the production of high conductivity copper wire, Blazey[184] emphasises that the ultimate criterion of success is whether, and to what extent, welds in rods become regions of weakness in drawn wire. His experiments showed no difference between the electrical resistance of wire with and without welds, while the welded joints had 98% of the tensile strength of the wire.

Warburton-Brown[185] has given a general description of brazing by induction, while a new book by Brooker and Beatson[186] covering all aspects of industrial brazing in an authoritative manner has appeared.

Powder Metallurgy

As a result of examining the effect of surface treatment on the sintering properties of metal powders, Naeser[187] concludes that the addition of phosphorus, in the form of ammonium phosphate, leads to a marked increase in the tensile strength of copper and iron compacts. Gupta[188] reports the successful production of aluminium bronzes from freshly reduced copper powder ball-milled with aluminium powder in different proportions, compacted, and sintered in pure hydrogen for 32 hours at 900° C., while Pawlek[189] has produced sintered copper having a conductivity of over 100% I.A.C.S. by powder metallurgy methods.

Greenwood,[190] reviewing powder metallurgy in relation to the automobile industry, points out that porous iron skeletons infiltrated with copper or copper alloys can be brazed to steel without the necessity for using a flux.

A recent patent[191] claims that strip can be produced by spraying metal on to a moving band to form a porous plate, which can afterwards be detached from its backing and consolidated by rolling. According to another patent,[192] the swelling which occurs when iron-copper compacts are sintered in hydrogen can be mitigated by including up to 3% of tungsten, either as the metal or in the form of an alloy or compound.

An account of the development of bronze colours from medieval times to the present day has been published by Rabaté.[193] A new patent in this field has been granted[194] according to which the powder is milled in the form of liquid suspension, and after being partially dried, is extruded through apertures, thus causing the lamellar particles to slide over each other with a burnishing action.

The issue of a comprehensive bibliography forming the third volume of Goetzel's "Treatise on Powder Metallurgy"[195] is to be welcomed, and another important compendium of general information is a recent symposium on the physics of powder metallurgy.[196] Of the 22 papers which it contains, four are concerned with copper and copper-base alloys.

Physical Metallurgy

Bullen, Head and Wood[197] have applied both metallographic and X-ray methods to an examination of the effects of fatigue on the structure of oxygen-free high conductivity copper. They found that when a symmetrical cycle in alternating tension and compression is built up faster than a certain critical rate, disorientation of the structure is largely suppressed. Internal movements under fatigue conditions do not necessarily cause strain hardening and, therefore, do not appear to occur by the usual slip mechanism of plastic flow. Teed[198] has approached an allied subject from the opposite angle, discussing the effect of variations in metallographic structure and crystal size on the fatigue properties of metals and alloys. He included both cast and wrought copper-base alloys in his extensive review.

The subject of internal stresses in metals has always been of particular interest to those concerned with the manufacture or use of brasses and other copper alloys, and for this reason a recent review of present knowledge in this field is welcome.[199] In it the author, Van Horn, deals with the conditions under which internal stresses can be set up in the metal, distinguishing between mechanical and thermal causes. He also describes the mechanical and thermal processes by which unwanted internal stresses can be eliminated. In this connection, Hanstock[200] has patented an interesting technique of reducing internal stresses in metals, particularly those which arise during quenching, by subjecting the objects to a thermal shock treatment.

Jenkins and Digges[201] have examined the influence of prior strain history on the mechanical properties and structures of copper. They suggest that partially cold-drawn copper exhibits strain-ageing effects when subjected to stresses in the vicinity of the maximum load, a phenomenon which has not apparently been previously recorded for copper. For copper, among other metals, Wooley[202] has studied the peculiar Bauschinger effect, which shows that if a work-hardenable material is deformed plastically under a particular tensile stress, unloaded and retested, it will deform under compression at a lower stress than in tension. Wooley finds that the strain associated with the process is approximately equal to the recoverable elastic strain after the preliminary cold working operation.

It has long been known that the electrical conductivity of metals and alloys is different when measured parallel or perpendicular to the direction of cold working. Broom and Clothier[203] have reported a series of careful experiments on drawn wires of copper, brass and aluminium bronze. Electrical anisotropy was found in all cases, and was appreciably greater for the alloys than for the copper. Some fresh figures for the thermal conductivity of copper, and of copper containing small quantities of phosphorus and iron, have been published by Goglia, Hawkins and Deverall.[204] From their results it would appear that the addition of iron to copper causes a reversal of the temperature coefficient of thermal conductivity. At two extremes of temperature, Scala and Robertson[205] have determined the electrical resistivity of copper and binary copper alloys containing

1% (atomic) each of zinc, aluminium, indium, tin and phosphorus in the molten condition, while Estermann, Friedberg and Goldman[206] have studied the specific heat of copper, among other metals, at temperatures close to the absolute zero. An extensive review of the properties of metals at low temperatures, particularly the physical properties, has been published by MacDonald.[207] Eggleston[208] has examined the effect of cold working copper by twisting it at $-269°$ C., followed by "annealing" at temperatures up to 50° C.

A careful investigation of the large crystal grains which are typical of annealed *beta* brass[209] has revealed that they are in reality colonies of much smaller grains. This type of structure was found to persist through hot working, and through the limited degree of cold working which can be applied to such material. In a somewhat similar research, Green and Brown[210] have shown that the degree of ordering of *beta* brass can be sufficiently influenced by heat treatment markedly to affect the mechanical properties.

Balluffi and Alexander[211] have referred to the fact, already fairly well known, that porosity is likely to arise during the diffusion of one metal through another, particularly if the components diffuse at different rates. They point out that this may be a source of error in the determination of diffusion constants. A useful review of diffusion and oxidation, covering over 100 references, has been published by Birchenall.[212]

Of more general interest are papers on the plastic behaviour of metals,[213-216] the mechanism of fatigue,[217, 218] the mathematics of creep[219, 220] and the effect of temperature on the hardness of pure metals, including copper.[221]

Miscellaneous

During the past few years, considerable interest has been shown, particularly in America, in the possibility of substituting other materials for the copper and brass normally used in the manufacture of car radiators, and aluminium, copper-clad or otherwise, has been among the substitutes tried.[222] It is encouraging for the copper industry that a team of experts, examining the matter on behalf of the Society of Automotive Engineers,[223] was reluctant to recommend any change from established practice.

Delay and even derailment of trains have been known to occur through the failure of journals. In an interesting series of practical trials Laudig[224] has concluded that the apparent embrittlement of the shafts can be attributed to the penetration of copper into the steel. Failure of lubrication may cause the white metal lining to melt away, allowing the shaft to run dry in the copper alloy axle box. His test showed that though running without lubrication in iron axle boxes led to temperatures quite as high as, if not higher than, in gunmetal, no cracking of the shafts occurred under such conditions. The work emphasises the need to ensure an adequate supply of lubricants.

A series of valuable articles on the mechanics of cavitation erosion has appeared,[225] and also some interesting photographs, by short duration flash, of the cavitation on the blades of a ship's propeller at sea.[226] These are believed to be the first of their kind to be published.

Brügger[227] describes new developments in the design of finned cylinders for air cooled internal combustion engines, whereby iron cylinders are cast on to plates of copper which form the fins. The high thermal conductivity of the copper greatly improves the efficiency of cooling. Rupture discs made of gilding metal for use as safety devices in chemical and similar processes conducted under pressure have been the subject of a publication by Prescott,[228] while a most authoritative and comprehensive review of British coinage has been published by Newman.[229]

"Copper Venture,"[230] a book on the discovery and development of the Roan Antelope and Mufulira copper mines of Northern Rhodesia should give pleasure to all who are interested in the red metal.

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Birmingham Productivity Association Secretary

BIRMINGHAM Productivity Association has appointed a full-time organising secretary. He is Mr. Ernest Tonkinson, a 37 years old expert in economic and commercial affairs, and he will have an office at Birmingham Chamber of Commerce. A statement from the Productivity Association refers to Mr. Tonkinson as "a man of unusually wide qualifications" and adds "His varied experience, academic attainments and knowledge of Birmingham, combined with a real interest in productivity based on economic considerations, eminently fit him for the post and we are confident of his success in it." Apart from assuming responsibility for the administrative machinery of the Birmingham Productivity Association, Mr. Tonkinson automatically becomes a member of the Association's Council and of its Action and Education Committee.

Change of Address

W. EDWARDS & CO. (LONDON), LTD., manufacturers of high vacuum equipment, have moved to their new premises in Crawley, and communications should now be addressed to the Company at Manor Royal, Crawley, Sussex. (Tel : Crawley 1500 (10 lines). Telegrams : "Edcohivac, Crawley.") The Scottish Branch remains at 44, West George Street, Glasgow.

A New Design of Wagon Tippler

A NEW wagon tippler designed to Railway Clearing House standards was recently completed by the Fraser & Chalmers Engineering Works of the G.E.C. Fully automatic in tipping operation, the machine is designed to handle wagons up to the standard Ministry of Transport pattern of 24½ tons capacity but will deal with smaller wagons down to 8 tons capacity.

The important feature of the tippler is that no clamping or binding mechanism is necessary and, consequently, the time cycle of operation is decreased by obviating the necessity to clamp the wagon as a separate operation. A further refinement is the provision of an adjustable side bolster beam for which a patent has been sought. It should be noted that the present railway regulations give two different heights for the side bolster beam, dependent upon the range of wagons being handled. Thus, for wagons from 6 ft. 6 in. to 8 ft. 6 in. high above rail level, one height is specified, while for wagons within the range of 8 ft. to 10 ft. 6 in. a different height is required. The difference between these two heights is 1 ft., and this is the range of movement of the adjustable side bolster beam, a feature which enables the full range of wagons from 6 ft. 6 in. to 10 ft. 6 in. high above rail level, to be handled in one machine. So far as is known, no tippler has previously been put forward capable of handling so extensive a range of wagons.

There are five main parts of the tippler :

(1) A rail frame or table forming a cradle on which the wagon is placed.

(2) A pair of lifting arms with rope cams attached, braced together in vertical and horizontal planes by built-up lattice girders forming the cradle arms. The vertical girder is arranged with heavy double beams at each end, and between these beams are placed mild steel pivot pins which form the connection between the cradle arms structure and the rolling arms structure. The pivot pins are arranged so that they are supported at both ends.

(3) A heavy horizontal double beam member, which rests at its ends on the vertical double beams mentioned above, and upon which are mounted the rubber-covered self aligning side bolster cushions, against which the side of the wagon rests during the tipping operation. This assembly is movable vertically to allow for various heights of wagons, its movements being controlled by two heavy screws operated by two electric motors through reduction gears mounted on the cradle arms structure. Behind this beam assembly, and attached to the cradle arms assembly, are spill plates so designed that the contents of wagons of any height within the capacity of the tippler are discharged to the hopper without spillage.

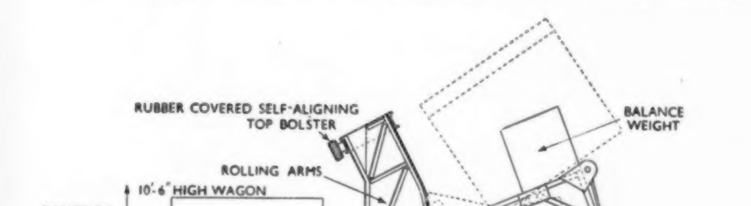
(4) A pair of rolling arms pivoted on the pins already mentioned are connected by a girder, attached to which are the top bolster cushions which secure the top of the wagon being tipped. This assembly rests upon, and in the final stage of tipping rolls along, a pair of rolling paths.

(5) A hoisting winch arranged for mounting in a pit below ground level at the side of the cradle remote from the receiving hopper.

The cradle rests upon solid foundations in its normal position, so that the tippler and ropes are not stressed by through traffic. The cradle is pivoted to the cradle arms by pins which are slightly eccentric, so that the natural tilt brings the wagon against the side bolster cushions during the early part of the operating cycle. This tilting tendency is controlled by two cam faces, which are attached to the hopper side of the cradle, and rest on the cradle-tilting rollers attached to the foundations.

The side bolster cushions are pivoted, and so arranged that they are aligned automatically to the side of the wagon, thus allowing for wagons of varying widths and angle of side. The rolling arms are bored out at their lower ends to fit the pivot pins attached to the cradle arms, whilst the faces of the rolling arms rest upon, and roll along, the rolling paths. Registration ropes are fitted to locate the rolling arms relative to the rolling paths. These ropes are attached one end to the rolling arms and the other end to the rolling paths.

Between the two rolling arms is the top bolster supporting girder, attached to which are rubber-covered self-aligning top bolster cushions. There is no positive connection between the cradle arms and the foundation, so that the cradle



End elevation showing the arrangement of the rolling paths, drive gear and adjustable bolster mechanism.

arm girders are free to rise as the rolling arms roll forward.

To reduce the amount of work necessary on the actual tippler structure during tipping, a measure of counter balancing is provided. The counterweights are mounted on the top of the rope-cams, close to the hoist rope attachment points, and their function is to bring the cradle arm structure into a condition just short of balance. The tippler will handle wagons of the following sizes :

Height from top of rail to top of wagon	6 ft. 6 in. to 10 ft. 6 in.
Width of body outside	7 ft. 6 in. to 8 ft. 8 in.
Length over headstocks	15 ft. 0 in. to 21 ft. 6 in.
Wheel Base	8 ft. 6 in. to 13 ft. 0 in.

The tippler will also accommodate all normal hopper wagons.

The hoisting gear is electrically driven by a suitable motor, the two drums being geared to the motor by means of a worm reduction gear and trains of machine-cut spur gears. A solenoid brake is provided to prevent " run back " in case of current failure. The power from the electric motor is transmitted to the gears through a hydraulic coupling.

The motor is under push-button control for hoisting and lowering, and to prevent over-winding the tippler when a fully tipped position is reached, an automatic cut-out is provided. A similar cut-out is arranged at the " down " position, to stop lowering automatically when the tippler is at rest upon the foundations. The operation of the adjustable side bolster is also under push-button control, enabling the operator to select the most suitable height for the wagon being handled. The side bolster is so fitted that it may be placed either in the raised or lowered position. Intermediate positions are not required.

To operate the tippler, a loaded wagon to be discharged is run on to the cradle and the brakes applied. Whilst this is being done the height of the side bolster beam is, if necessary, adjusted by selecting the appropriate push button, the correct position for the bolster beam being determined by the height of the wagon. The electric hoisting gear is then put into action. The cradle arms start to rise, and the cradle with the wagon is gradually inclined towards the hopper, the action being controlled by the cradle pivots and cradle cams working on the cradle-tilting rollers supported on the foundations. This preliminary action is concluded when the side of the wagon comes into contact with the side bolster cushions.

The hoisting being continued, the wagon cradle and cradle arms form one unit, and revolve about the trunnion pins until the top of the wagon meets the top bolster cushions attached to the top bolster girder, and this now forms the final unit which on continuing to hoist revolves and rolls along the rolling path until the load is fully discharged. The hoisting gear is then reversed, the wagon brought back to the original position ready for removal and replacement by a further loaded wagon.

Dollar Pipe Order

STEWART & LLOYDS, LTD. have received through Williams Bros., the well-known American contractors, an order for several hundred miles of line pipe for the Haines-Fairbanks pipe project in British Columbia and Alaska. The value of the order, which has been secured in face of international competition, is approximately £1,000,000, and it will be paid for in dollars. The manufacture of the pipe will be undertaken in the Company's works in Glasgow, South Wales and the Midlands.

Aluminium " Palace " for Arab King

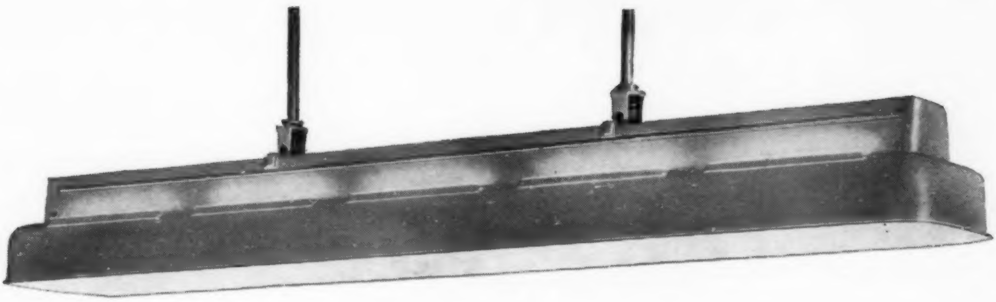
A PREFABRICATED " palace," made up of a cluster of aluminium buildings with inter-connecting passageways, has been delivered to the new King of Saudi Arabia, Saud Ibn Abdul Azziz. The order was placed with Booth & Co. (England), Ltd., and comprises three Altents and an Ovaltent. All are made of BA.60 aluminium alloy sheet supplied by the British Aluminium Company. The King's initiative in ordering factory-made buildings brought the prefabrication industry good publicity in the national press, and his action may have widened the British market for these buildings.

Buildings sufficiently strong to withstand the varied conditions of the desert were essential. It was stipulated that they must be resistant to corrosion, without fire risk and not requiring skilled maintenance. The natural qualities of the aluminium satisfied these conditions and also provided a cool interior. The plans were approved by the King when Crown Prince. So that the traditional Arab atmosphere of a tent should not be lost, one of the Altents was lined with wall and ceiling panels of green cloth, each panel embroidered with the royal arms of a palm tree above crossed swords. The interior resembles a tent save that windows have been cut in the " tent " sides to show the standard window frames.

The buildings are to be used as a hunting lodge by the King—he is styled Lord of Arabia—and his retinue. For their comfort, an aluminium shower cabinet and a prefabricated water tower have also been sent out to Arabia. The cabinet is Booth's well-known "Alspring" and the 9-ft. tower is made of their " Rite Angle " constructional steel.

British Chemical Abstracts

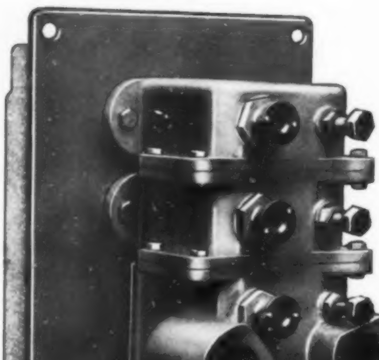
THE Society of Chemical Industry has, since 1885, provided its members with abstracts of publications on applied chemistry. For some considerable time this service has been provided through British Abstracts, published under the direction of the Bureau of Abstracts. This organisation will cease to exist at the end of this year and British Abstracts, in their present form, will no longer be published after December 31st, next. The Council of the Society, faced with this position, has decided to resume the publication of abstracts on applied chemistry on its own account and to revert to the position as it was before the formation of the Bureau. The Abstracts will appear monthly, separately paged, in the *Journal of Applied Chemistry* and the *Journal of the Science of Food and Agriculture*, whichever is relevant to the subject of the paper abstracted. Broadly speaking, Abstracts hitherto covered by B I and B II will appear in the *Journal of Applied Chemistry* and those covered by B.III in the *Journal of the Science of Food and Agriculture*. Abstracts will not be available apart from the Journals, and applications for copies should be made to the Society of Chemical Industry, 9–10 Savile Row, London, W.1.




ASHLEY

THERMIC C C GAS BURNERS

(CONCENTRATED COMBUSTION)



THE UNIT SYSTEM OF CONSTRUCTION

Unit-construction enables these burners to be used either singly or in multiple form to accommodate varying lengths of furnace.

Experience has proved conclusively that a multiplicity of small burners with separate feeds for the gas consumption required are preferable to, and more economical than a smaller number of large burners.

Applications of the C.C. principle include annealing ; local hardening ; bolt heading ; steel forging including stamping, upsetting, billet heating and rolling ; fire welding ; brazing—cycle forks, handlebars and liquid brazing ; high-speed steel hardening ; tungsten wire heating ; aluminium melting and maintaining ; glass melting and glory holes; tube annealing and tube upsetting ; salt tempering and hardening.

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M-W. 308

Carbon in the Engineering and Metallurgical Industries

V—Chemical, Mechanical and Electrical Uses

By V. S. Kingswood, M.Sc., B.Sc., F.I.M.

Deputy Head of the Metallurgy Department, Battersea Polytechnic

In the previous article in this series, the application of carbon and graphite products in the metallurgical field was discussed. Attention is directed in this concluding article of the series to chemical, electrical, mechanical and miscellaneous applications.

EARLIER articles in this series have discussed the production and properties of carbon and graphite products, and in the November issue the application of these materials in the metallurgical field was described. In concluding the series, the present article refers to applications in the chemical, electrical and mechanical engineering fields, and to miscellaneous applications in other industries.

CHEMICAL ENGINEERING APPLICATIONS

During the last 20–25 years the use of carbon and graphite as materials of construction in chemical engineering has become increasingly popular, in view of the superior corrosion resistance of these materials compared with that of the metals and alloys normally used for this purpose.

Relevant Properties

Important properties to be considered may include any or all of the following, depending on the application :

Purity.—Whereas the purity of carbon or graphite may not be of vital importance for furnace work, in certain chemical processes (e.g. spin baths in the rayon industry) no contamination of the solutions present must result from the material used for plant construction. Graphite is very suitable for meeting these demands.

Thermal Conductivity.—A wide range of values for thermal conductivity is possible with carbons and graphites, depending upon the proportions of these materials in the mixture used. In this way, both thermal insulation and high conductivity may be obtained, coupled with the inherent chemical inertness to most corrosive materials.

Thermal Shock.—Graphite, owing to its low coefficient of expansion and high thermal conductivity, will tolerate thermal extremes without fracture.

Electrical Conductivity.—Compared with the metals, both carbon and graphite may be considered as insulators, but both carry current to a varying degree,* and this feature must be considered when these materials are used for tank linings or ducting in processes involving electrolysis in aqueous solutions, or in cases where an electric current is passing through a solution contained in a lined vessel.

See Table I on p. 171 of the October issue and Table II on p. 224 of the November issue.

Porosity.—This property has been considered fully in a previous article and, apart from aeration, gas diffusion or filtration applications, an extremely low porosity is imperative for most chemical processes. Impervious carbon and graphite shapes are available to meet most requirements.

Corrosion Resistance.—In general, both carbon and electrographite are very resistant to chemical attack by all substances except those of a strongly oxidising character. The main weakness in chemical plant construction using these materials is frequently the chemical-resisting cements used in jointing the various component members. It has been found in nearly all test cases that any failure due to chemical attack is first evident in the cement joint, and, therefore, it is essential to know the chemical limitations of the jointing materials, which are very similar in constitution to the resin mixtures used in rendering carbon and graphite shapes impervious. Table I shows the corrosion resistance of chemical cements to many common reagents and mixtures of industrial importance.

Ease of Fabrication.—It has already been shown that a wide variety of shapes may be pressed, extruded or tamped in carbon-base mixtures, and that machining to close limits may also be performed with ease on graphitic carbons and electrographite. These conditions fulfil most requirements of the chemical engineer.

Wood Pulp Digesters

The following review of applications will suffice to show the wide scope for using these non-metallic materials in a variety of chemical processes.

Carbon tubes for use in Cottrell electrostatic precipitators dealing with phosphoric and sulphuric acid mists was one of the first chemical engineering applications, as long ago as 1927. At about the same time, interest was shown in carbon linings for wood pulp digesters, particularly those working on the sulphate process (for kraft paper and cardboard manufacture) and sulphite process (for high-quality paper and cellulose for the rayon industry). In these processes, wood chips are digested for several hours in solutions containing calcium or sodium bisulphite and sulphurous acid (sulphite process), or caustic soda and sodium sulphate and sulphite (sulphate process),[1] at about 150° C. and a pressure of 100–150 lb./sq. in. The vessels are very large vertical cylinders, with conical or hemispherical ends, made from ¾–1 in. riveted steel plate. Originally,

TABLE I.—CORROSION RESISTANCE OF CARBON, GRAPHITE AND CHEMICAL RESISTING CEMENTS

Chemical	Concentration	Temp. °C.	Result
ACIDS			
Acetic acid	Glacial	90–100	A
Hydrochloric acid	All concentrations	Up to 100	A
Hydrofluoric "	40%	Up to 100	A
" "	60%	100	A
Lactic acid	Sp. Gr. 1·21	90–100	A
Nitric acid	8%	95–100	A
" "	10%	Up to 100	A
" "	12%	70	A
" "	12%	95–100	C
" "	15%	50	A
" "	15%	95–100	C
" "	20%	18–25	A
" "	50%	18–25	C
" "	Conc.	All temps.	C
Phosphoric acid	96%	95–100	A
" "	100%	50	A
" "	100%	150	A
" "	100%	200	A
" "	100%	260	C
Sulphuric acid	12%	90–100	A
" "	20%	Boiling	A
" "	50%	18–25	A
" "	50%	50	A
" "	50%	95–100	A
" "	65%	18	A
" "	65%	95–100	A
" "	86%	18–25	A
" "	Conc.	18	C
" "	Conc.	50	C
Tannic acid	Saturated	90–100	A
ACID MIXTURES			
Chrome plating solution	CrO_3 –300g/1, H_2SO_4 –2%	60	C
Copper plating solution	$CuSO_4$ –200g/1, H_2SO_4 –30g/1	18–25	A
Hydrochloric acid + nitric acid	1 + 7%	70	A
" " " "	50 + 8%	80–90	A
Hydrochloric acid / + Nitric acid / + Sulphuric acid	5% / 5% / 5%	95–100	A
Hydrofluoric acid + nitric acid	5 + 20%	60	A
" " " "	20 + 10%	18–25	A
" " " "	20 + 10%	95–100	A
" " " "	5 + 30%	70	A
Hydrofluoric acid / + Sulphuric acid	5% / 5%	18–20	A
Phosphoric acid / + Fluosilicic acid / + Hydrofluoric acid / + Sulphuric acid	30–40° Be / 1% / 2% / 1%	70–80	A
Sulphuric acid / + Sodium chloride / + Sodium hydrosulphite	50% / 0·4% / 0·5%	90–100	A
Sulphuric acid / + Sodium sulphate / + Zinc sulphate / + Magnesium sulphate	10% / 12% / 0·5% / 5%	70–80	A

Chemical	Concentration	Temp. °C.	Result
ALKALIS			
Ammonium hydroxide	Sp. Gr. 0·880	90–100	A
Sodium hydroxide	20%	18	B
" "	20%	95–100	B
" "	50%	90–100	B
Potassium hydroxide	20%	18	B
" "	20%	95–100	B
SPECIAL TEST			
Alternate immersion in sulphuric acid (30%) and caustic soda (10%) with 48 hours in each liquid for a total of 1,200 hours		95–100	B
MISCELLANEOUS (INORGANIC)			
Ammonium persulphate	Saturated	18	A
Bleaching powder	Saturated	18–20	A
Carbon dioxide (solid)	100%	Minus 79	A
Chlorine gas	100% (dry)	18–25	A
" "	100% (wet)	18–25	A
Cupric sulphate	Saturated	90–100	A
Cuprous chloride in hydrochloric acid	Saturated	90–100	A
Ferric chloride	Saturated	100	A
Ferrous sulphate	Saturated	90–100	A
Iodine in potassium iodide	1·5 g/1, 110 g/1	90–100	A
Mercuric chloride	Saturated	90–100	A
Mercurous chloride	Saturated	90–100	A
Potassium dichromate	Saturated	95–100	A
Sodium bisulphite	30%	25–35	A
Sodium carbonate	Saturated	50	A
Sodium chloride	Saturated	50	A
Sodium sulphide	Saturated	25–35	A
Sulphur dioxide	100% (dry)	40–45	A
Zinc chloride	40–50° Be	85	A
MISCELLANEOUS (ORGANIC)			
Acetone	100%	Boiling	A
Beer (stale)	100%	18	A
Benzene	100%	Boiling	C
Carbon disulphide	100%	18	C
Cresylic acid	99% pale	90–100	C
Ethyl alcohol	100%	Boiling	A
Furfural	100%	50	C
Linseed oil	100%	18	C
Mineral oil	100%	18–20	B
Mineral oil	100%	50	B
Mineral oil	100%	75–85	B
Pine-tar oil (crude)	100%	Boiling	C
Tar oil	100%	90	C
Trichlorethylene	100%	18	C
Turpentine (crude)	100%	Boiling	C
White spirit	100%	Boiling	C

" A " signifies that the cement is completely resistant to the reagent. " B " signifies that the cement is completely resistant to the reagent, but only after heat treatment for 12 hours at 60°–100° C. For mechanical reasons this heat treatment is always advisable even for chemicals in category " A." " C " signifies that the cement is attacked or weakened and cannot be recommended.

linings were of acid-resisting siliceous brick, but with the chemical attack of the solution and movement of the riveted shell due to " breathing " (when the digester is emptied it is washed out with cold water sprays) the lining disintegrated within 2–3 years. Carbon linings have given 5–8 years life and will probably last longer when welded shells have become standard practice.

For this application, where abrasion from the wood chips must also be considered, a lining of hard carbon tiles (normal porosity) jointed and backed by a membrane of chemical-resisting cement is preferable and less costly than using impervious carbon tiles. This construction would then be similar to that shown in Fig. 1.

Pickling Tanks

Pickling tanks of similar construction are becoming increasingly popular in the steel industry, when mixtures of nitric and hydrochloric or hydrofluoric acids are used for descaling stainless steels. Again, the hard carbon tiles protect the chemical-resisting membrane from mechanical damage.

The development of impervious graphite heat exchangers for a wide variety of processes has made rapid strides in both design and efficiency. First a simple coil type was used (similar to Fig. 2), then the more robust plate heater (Fig. 3), and in the last 12 years tube bundles (impervious graphite tubes in a fixed or " floating " head) (Fig. 4) and bayonet heater sheaths (for electric immersion heaters) (Fig. 5) have been developed.[2]

For gas absorption, carbon towers constructed from sections to give a total height of 40 ft. × 33 in. diameter (internal) and packed with Raschig rings are being used. Pipes, pipe fittings, ducting and centrifugal pumps, all fabricated from impervious graphite or carbon, complete the brief picture of the uses to which these materials may be applied in the chemical industries.

ELECTRICAL ENGINEERING APPLICATIONS

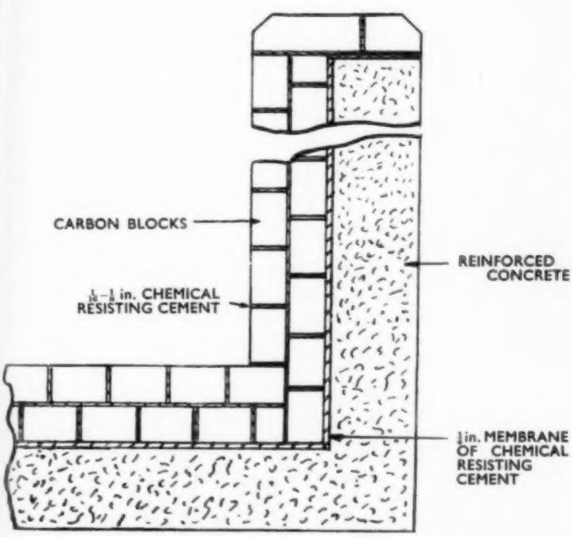
These materials are used in a wide range of electrical engineering applications, which include : carbon brushes; arc lighting electrodes; current collecting skids; carbon pile resistance elements ; high purity graphite for thermionic valve anodes and grids ; radio resistances ; and carbon granules for sound transmission by means of the telephone or microphone.

Carbon Brushes.—To fulfil a wide range of service conditions (load, speed and commutation) very many brush grades exist. Mixtures used incorporate the usual carbonaceous materials such as natural graphite, retort

carbon, lamp black, petroleum coke bonded with pitch, tar or synthetic resins, and for certain applications metal powders are incorporated in the mixture. Most brushes are carbon-base with small additions of natural graphite to improve conducting and lubricating properties. Manufacture is very similar to that described for both carbon and electrographitic electrodes, but in certain cases hot pressing of brush mixtures is carried out, especially with resin-bonded grades. The kilned articles are ground to shape and the copper leads riveted or bolted to one face, which is often copper sprayed to give better contact. Some brushes have their leads moulded within them during pressing.

Arc Lighting Electrodes[3].—These are carbon shells filled with a core mixture containing rare earth salts, principally those of cerium. A typical cinematograph lamp having 7 mm. electrodes carrying 50 amp. is said to produce an arc light equivalent in colour to a temperature of 6,000° K. Most shells have an exterior copper plating to protect the carbon from atmospheric oxidation in service.

Current Collecting Skids[3].—These are hard dense graphitic carbon inserts for fitting in appropriate metal

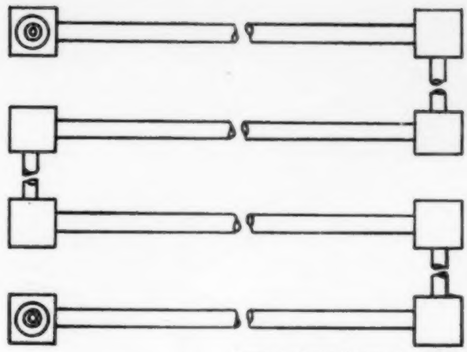


Courtesy of Carblox, Ltd.

Fig. 1.—Permeable carbon tank lining with impervious membrane backing.

shoes. By sliding contact with current-carrying overhead wires, electricity is transmitted to the motors of cranes, trams, trolleybuses and trains. It is claimed that the lubricating properties of the carbon skid give a greater life to the overhead wire than was possible with the original copper collectors.

Carbon Pile Resistance Elements[3].—These consist of a stack of carbon plates, discs or rings whose resistance varies with the pressure applied to the ends of the pile. The change in contact resistance is very pressure sensitive and enables a wide range of resistance to be employed with any one unit. Furthermore, since the current must traverse the whole pile, heating effects are uniform and more quickly dissipated than with the wire-wound type of variable resistance.



Courtesy of The Morgan Crucible Co., Ltd.

Fig. 2.—Carbinert heating coil.

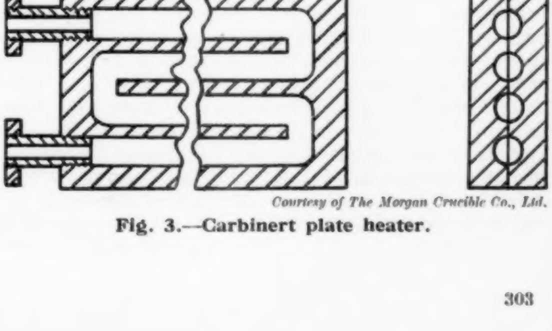
Carbon Granules.—In the microphone and telephone use is made of the same principle of carbon-to-carbon resistance varying with pressure. Here the pressure of sound waves impinging on a sensitive diaphragm imparts a pressure to the carbon granule packing, the varying resistance of which controls the magnitude of the current passing from a carbon electrode on its way to an amplifier.

MECHANICAL ENGINEERING APPLICATIONS

The principal mechanical application of carbon is undoubtedly that of bearing manufacture for arduous working conditions involving high temperature or corrosive atmosphere, or for inaccessible bearings where lubrication would be difficult. This gives a convenient division for the type of bearing used, in that the first set of conditions may necessitate the use of a hard graphitic carbon bearing devoid of oil, and depending entirely on the low friction properties of graphite against metals. The value for the coefficient of friction of carbon on steel has been quoted as 0·12,[4] which is higher than for lubricated metal bearings, but is very suitable for high-temperature applications such as exist with bearings on travelling grates in mechanical stokers used in power station boilers. It has been stated that such bearings may reach a temperature of over 300° C. in service, and operate in the presence of fuel ash. Despite these conditions, in which an oil-lubricated bearing would be useless, the rate of wear was only 0·009 in. in two years against 0·3 in. in four months for cast iron.

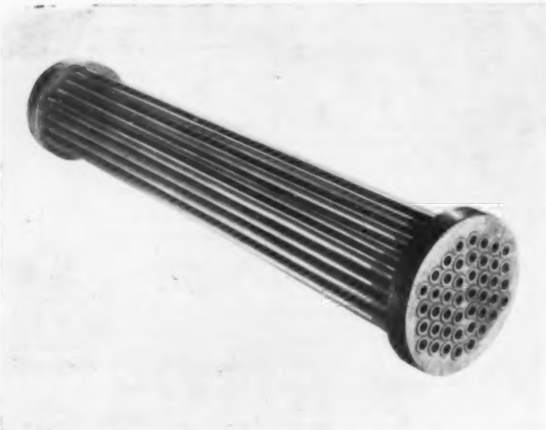
Another example is the use of carbon bearings in conveyor plants for the stove enamelling and Bonderizing of steel parts, where the bearings are subjected to heat, degreasing vapour, phosphate salts, steam and stoving ovens.

In general, carbon bearings operate efficiently even when immersed in liquids such as petrol, paraffin, water, brine and caustic alkalis.



Courtesy of The Morgan Crucible Co., Ltd.

Fig. 3.—Carbinert plate heater.



Courtesy of The Morgan Crucible Co., Ltd.
Fig. 4.—Impervious graphite tubes.

The second type of bearing, for use in inaccessible parts of machines, or where external oiling is undesirable owing to contamination of the work handled by the machine, is the porous, oil-retaining sintered metal bearing, which frequently contains graphite for added lubrication. These find extensive application, from domestic fans, electric clocks, vacuum cleaners, washing machines and refrigerators to industrial tractors and other vehicles, bottle filling machines and laundry, textile, paper making and printing machines, to quote but a few examples of use of this very versatile material.

Comparatively minor applications of carbon in the mechanical engineering field include piston rings, shaft seals on reciprocating pumps, rotary or sliding valves used for metering petrol or corrosive fluids, and metal-carbon clutch facings.

MISCELLANEOUS APPLICATIONS

Other applications include graphitic carbon moulds and formers used in the glass industry; the use of graphite compounds for lubrication; and activated carbons for gas and metal adsorption.

For the *glass industry* use is made of the non-wetting of graphite by molten glass, its resistance to thermal shock, and its low thermal expansion (compared with most glasses), in the manufacture of moulds and formers for ground necks and stoppers of glassware. Machined plates of graphite for containing optical lenses during annealing, and glass blowing moulds for scientific apparatus are other applications.

As a *lubricant*, graphite has been used alone or associated with oils or greases for about 100 years. Both natural and artificial graphites are suitable, but carbons are abrasive. Graphite in use fills the pores of the metallic materials with which it is in contact, and so decreases the coefficient of friction by the fact that graphite-to-graphite films now exist as the bearing surfaces. For industrial lubrication, dry natural flake graphite may be used or the graphite may be compounded in greases and oils. In the latter case, it has been found that flocculation tends to occur when flake graphite is used, due to the fact that even after grinding the flake characteristics are retained. Proprietary graphite suspensions in oil (for lubrication) or in water (for mould dressing) are said to be made by air floating finely ground electrographite and mixing to a paste with a dilute aqueous tannin solution (said to prevent flocculation) in a suitable mill. For lubrication purposes, this water paste is again milled with oil additions which eventually displace the water to give an oil paste which can be diluted further with light lubricating oils.

The use of *activated carbon* as a gas or metal adsorbent and for decolourising solutions covers a wide industrial field, but the latter application, since it applies mainly to food and drug purification processes, will not be considered in this paper.

Charcoal used for the purpose of adsorbing gases was first reported about the middle of the 19th century. Since then, various chars have been made from such materials as coconut and other nut shells, fruit pips, various woods, sugar and cokes, but the first-named material is found to produce the most efficient gas adsorbent char after retort distillation at about 950° C., followed by steaming at that temperature.

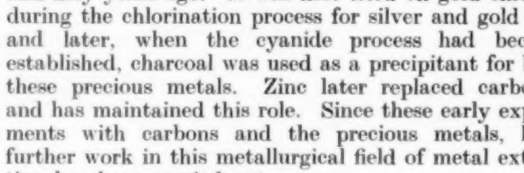
This activation process is said to increase the number and internal surface of the charcoal pores, which appears to increase its adsorbing capacity. Gases or vapours with a high boiling point are more readily adsorbed by activated carbon than those with lower boiling points. The carbon adsorbent is normally used in granular form, in layers from a few inches to several feet in thickness. Apart from a high adsorptive capacity, an efficient char should easily release its adsorbed vapour after a simple low temperature steaming. Many volatile hydrocarbons are recovered from industrial gases in this fashion.

Activated charcoals were used for precipitating certain metals from a solution of their salts as early as a hundred and fifty years ago. It was first tried on gold chloride during the chlorination process for silver and gold ores and later, when the cyanide process had become established, charcoal was used as a precipitant for both these precious metals. Zinc later replaced carbon—and has maintained this role. Since these early experiments with carbons and the precious metals, little further work in this metallurgical field of metal extraction has been carried out.

FUTURE APPLICATIONS

In this series of articles, a critical review has been given of ancient and modern applications of all three forms of carbon. Applications which require the special properties possessed by carbons, graphites, or even the diamond, have been developed, and are now common practice.

For the future, an extended usage of these materials will undoubtedly develop, and it may well be that in this age of atomic energy and jet propulsion the non-metal carbon may replace the more usual metallic materials. It was reported as long ago as 1945 in the U.S.A.[5] that high purity graphite was playing its part as a moderator in the plutonium piles at the University of Chicago, and experiments of an exploratory nature have also been carried out using copper-graphite moulded components for handling high temperature exhaust gases in rocket type guided projectiles.



Courtesy of The Morgan Crucible Co., Ltd.
Fig. 5.—Bayonet sheath for electric immersion heater.

The author can foresee a wide new field of application for carbon as a refractory in normal atmospheres if only some form of protective coating can be given to the material. Preliminary experiments on this project carried out by the author showed promising results, but much has still to be done to make the process an economic possibility.

Advancement in existing spheres of application is certain, in the extended use of carbon linings for smelting furnaces and for moulds or liners in centrifugal casting. Machined intricate graphite moulds should prove less expensive during short runs for certain alloy castings than the use of alloy steel moulds as at present.

Graphite teeming nozzles and moulds for continuous casting, and undoubtedly the extended use of carbon and graphite plant in chemical engineering, are further fields for development work.

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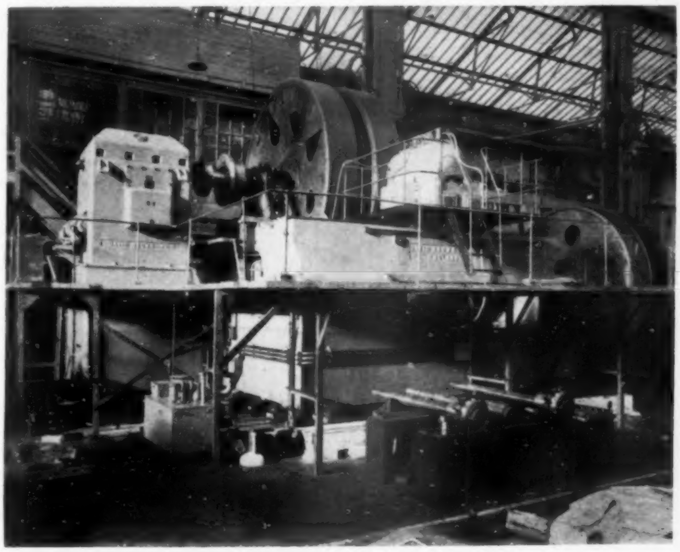
World's Largest Turbine Gear Shaving Machine



THE world's largest turbine gear shaving machine, designed and built by the Manchester firm of David Brown Machine Tools, Ltd., is now in operation at the Clydebank shipbuilding works of John Brown & Co., Ltd. Weighing 130 tons, this massive machine can, if necessary, accommodate turbine gear wheels of 220 in. diameter, and weighing 100 tons.

This machine was installed for the treatment of marine main propulsion wheels, and is being used in conjunction with a David Brown 48 in. pinion shaving machine, which is employed for shaving H.P., I.P. and L.P. pinions. The wheel shaving machine is designed for "crowd" shaving, which is a super-finishing process for removing the minute undulations inherent in gears cut by the hobbing process.

The cutter head of the machine is equipped with a brake on each side of the cutter so as to permit selective shaving, which may be necessary to obtain something of the order of a 95% bearing across the facewidth of the gear, allowing for slight relief at the ends. In cases where a pre-calculated amount has to be allowed for the torsional deflection of the pinion under full load, the necessary adjustment in the shaving process is carried out on the pinion machine ; this usually applies to H.P. pinions of comparatively small diameter. A feature of the 220 in. machine is that it is fitted with a pinion mounting bracket at the rear, allowing the machine to be used as a testing bed so that the tooth marking can be determined without removing the large wheel from the shaving machine.

The machine is of massive proportions, being of 33 ft. length with a fore and aft dimension of 35 ft. and a total height of 16 ft. The bed is sunk into the ground by 3 ft. and the layout provides easy access to the machine. The main bed comprises two very heavily ribbed castings tenonned and bolted together, on which are mounted the shaving head slidebed, the wheel pedestals, and the bracket for the pinion pedestals. By adjusting the shaving head slidebed on the main bed of the machine, gears of any centre distance from 48 in. up to the maximum diameter of 220 in. can be accommodated. The cutter has maximum traverse of 100 inches, and a similar wheel face width is within the capacity of the machine. With a bore of 2½ in. the cutter diameter ranges from 8 to 14 in.

The main drive to the wheel is by a 30 h.p. motor, the work speed being variable between 7 and 30 r.p.m. by means of pick-off gears. The drive to the saddle feed motion is by an independent 6 h.p. motor and, by the use of pick-off change gears, saddle cross feeds of between 0·03 in. and 0·7 in. are available. A self-contained and independently motor-driven pump, strainer and oil reservoir unit is provided.

A noteworthy feature is that the operating drive is applied to the wheel which is being shaved. There is no rotational drive to the cutter, which is driven by contact with the main wheel. The power drive to the cutter head is solely for the purpose of controlling the traverse of the saddle. Small primary wheels can be accommodated by the provision of appropriately proportioned pedestal supports mounted on the large pedestal bases.

To facilitate the setting of the machine, the saddle is provided with a quick power motion of 36 in./min. and the shaving head has a rapid traverse speed of of 12½ in./min. Movement of the shaving head can be accomplished with a motion of 0·01 in. per revolution of the hand-wheel.

The accompanying illustration shows the machine mounted on the shop floor as a temporary expedient, so as not to delay an important shipbuilding contract, but the machine will ultimately be moved to an adjacent extension where it will be sunk in the floor.

New and Revised British Standards

Electroplated Coatings of Nickel and Chromium (B.S. 1224 : 1953) Price 2s. 6d.

The principal reason for the revision of B.S. 1224, which was originally published in 1945, is that the original document did not fully meet the requirements of the motor car industry, and the document has been extended to cover coatings on materials other than steel and copper. The standard has been drawn up with a view to specifying the essential qualities of the coatings in question. It is realised that it is impossible at the present time to specify completely every factor affecting the performance of an electroplated coating.

An important feature of this standard is the minimum thickness of the deposit, and particular attention is drawn to the effect of the contour. The requirements for minimum thickness normally apply only to those portions of the significant surface which can be touched by a ball of 1 in. diameter. It is hoped, therefore, that manufacturers will allow this vital consideration of surface contour to influence the design of any article on which a durable electroplated coating is essential.

It has not been found possible to specify average thicknesses as these vary considerably with the size and shape of the article and the method of plating. It was also impracticable to give guidance on the usage of the various classifications due to the difference in requirements. It is pointed out that the importance of conserving nickel has been taken into account in the preparation of the document by specifying alternative coatings using copper undercoatings ; particular attention is drawn to these coatings. Additionally, a salt spray test has been specified and appendices give details of the methods by which the tests should be carried out.

Dimensions of Collapsible Tubes with Short Screwed Nozzles (B.S.2006: 1953) Price 2s. 6d.

Collapsible tube manufacturers have been working for some years towards the specification of accurate dimensions for tubes, and a British Standard has now been issued for the dimensions of collapsible tubes with short screwed nozzles. It will relate to tubes for a wide range of pastes and semi-liquid materials such as medical and toilet preparations, concentrated food-stuffs, rubber solutions and shoe creams. For certain commodities it is necessary for technical reasons to alter lengths, wall thicknesses and weights. This is also necessary for products for which winding keys are used. The standard is not intended to cover such special requirements, but it is hoped that users of collapsible tubes will endeavour, as far as possible, to restrict their requirements to the range of sizes laid down in the standard. The standardisation of collapsible tubes with other types of nozzles is being considered, and if this proves practicable, the standard will be extended in due course.

Dimensions of X-Ray Films for Crystallography (B.S.2030:1953) Price 2s.

The special needs of crystallographers cannot be satisfactorily met by the sizes of X-ray film specified in B.S.1443, "Sizes of X-Ray Film and Intensifying Screens," and this standard B.S.2030 has, therefore, been prepared to deal with the sizes of X-ray film used in the various instruments peculiar to the crystallographer, e.g. diffraction powder cameras as specified in B.S.1693. It is hoped that this British Standard will give guidance relating to the future design of crystallographic equipment and apparatus.

Aluminium Bronze Rods, Sections and Forgings for General Engineering Purposes (B.S. 2032 : 1953) Price 2s. 6d.

Aluminium Nickel Iron Bronze Rods and Forgings for General Engineering Purposes (B.S. 2033 : 1953) Price 2s. 6d.

These standards have been prepared to reduce the number of alloys in this field, the two compositions chosen being those which have characteristics and mechanical properties which cover as far as possible all known applications. In B.S. 2032, the composition is a compromise between those of two Ministry of Supply material specifications D.T.D. 160, 'Aluminium Bronze for Valve Seats' and D.T.D. 174 'Aluminium Bronze Sand or Die Castings,' while in B.S. 2033 it approximates to that of D.T.D. 197 'Aluminium Nickel Iron Bronze Bars, Forgings and Stampings.' It is hoped that these two British Standards will be used wherever aluminium bronze is required for general engineering purposes.

Protective Transformers (B.S.2046:1953) Price 7s.6d.

This new standard deals with the performance requirements and special characteristics applicable to current and voltage transformers intended for protective purposes in non-balanced protective equipment, and for operation of earth fault devices with time-lag characteristics. Many of the requirements relating to such transformers are similar to those for transformers covered by B.S.81–"Instrument Transformers." For this reason, many of the clauses in B.S.81, especially those concerned with insulation, have been embodied in the new standard with little or no alteration, and it is made clear where this has been done.

The standard is divided into three main sections; the first deals with matters which in general are common to both protective current and protective voltage transformers, and includes clauses which define the various terms used and specify the nature of the high-voltage tests to be applied. The second and third sections deal more specifically with the requirements relating to current and voltage transformers respectively, e.g. with rated burdens.

The standard also includes appendices which describe, among other matters, the factors to be taken into account in order to determine the rating of a protective transformer and give examples relating to the air-current rating of current transformers. Particulars are also given of methods of temperature measurement, and of the information required by the manufacturer in order to supply transformers to this standard. Figures are included to show methods of terminal marking and the circuit arrangements for measuring the errors of residual voltage transformers.

99% Aluminium Tubes (not tested hydraulically) for Aircraft (L.67:1953) Price 1s.

This specification is complementary to British Standard L.54, which covers tubes of the same composition required to be hydraulically tested.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park St., London, W.1.

NEWS AND ANNOUNCEMENTS

Institute of Metals

Metal Working Lubricants Discussion

An Informal Discussion on "Lubricants for Metal Working Operations in the Non-Ferrous Metals Industry," arranged by the Metallurgical Engineering Committee of the Institute of Metals, will be held at the University, Edgbaston, Birmingham, on Wednesday, 6th January, 1954, from 10.30 a.m. to 4.30 p.m. The Chair will be taken by Mr. W. J. Thomas, M.I.Mech.E. Members and visitors who desire to do so, may obtain lunch (4s. 6d., including coffee) in the University Refectory, provided that they notify the Secretary of the Institute (at 4, Grosvenor Gardens, London, S.W.1), to that effect. No tickets are required and visitors will be welcome.

The discussion will be organised as follows, and will *not* cover lubrication in machining operations or the lubrication of machinery, bearings, etc.

Morning Session.

1. Lubricants for the hot-working of light metals.
2. Lubricants for the hot-working of other non-ferrous metals and alloys.

Afternoon Session.

3. Lubricants for the cold-rolling of non-ferrous metals and alloys.
4. Lubricants for the cold-drawing of non-ferrous metals and alloys.

Students' Essay Competition

Those intending to enter for the Institute of Metals Students' Essay Competition are reminded that the manuscripts of essays must reach the Secretary of the Institute at 4, Grosvenor Gardens, London, S.W.1, on or before January 1st, 1954.

Wakefield-Dick Sales Conference

The inaugural Sales Conference of the Wakefield-Dick Industrial Lubricants Division of C. C. Wakefield & Co., Ltd., took place in Liverpool recently, under the chairmanship of Mr. R. J. Turner and Major Cyril Dennis, Joint General Managers of the Division. An important feature of the Conference was a visit to the Company's new Stanlow installations where the delegates were conducted round the plant in several parties. This tour was followed by talks by A. V. Jay, Manager Lubrequipment Department and L. J. Field, Manager Mechanical Appliances Department on the application of lubricating equipment in industry. The proceedings concluded with an informal dinner at the Adelphi Hotel at which the speakers included the Joint General Managers and also Mr. M. Nicol and Mr. W. A. Hill who spoke in appreciative vein on behalf of the field sales force.

Corrosion Protection by Paint

A series of eight lectures on topics concerning the protection of metals by painting will be held at the Battersea Polytechnic at 7 p.m. on successive Thursday evenings, commencing on January 28th, 1954. The course has been organised in conjunction with the Corrosion Group of the Society of Chemical Industy and the Oil and Colour Chemists Association, and the panel of lecturers includes Mr. G. P. Acock, Mr. H. Hollis, Mr. H. Diamond, Dr. S. R. W. Martin, Dr. J. E. O. Mayne, Mr. R. E. Shaw, and Mr. J. F. Stanners.

The topics to be dealt with include: preparation for painting; painting for outdoor and immersed service; painting for special duties; inspection, cleaning and maintenance of painted metal; testing paint coatings; and mechanism of the prevention of corrosion by paints. In connection with the course, an exhibition of protective methods for preventing the corrosion of steel will be held at Battersea Polytechnic on Friday, January 21st, 1954, from 10 a.m. until 5 p.m.

The fee for the course of eight lectures is £1. Further particulars and application forms can be obtained from the Secretary (Paints Course), Battersea Polytechnic, London, S.W.11.

Royal Society Medal Awards

Her Majesty the Queen has been graciously pleased to approve recommendations made by the Council of the Royal Society for the award of the two Royal Medals for the current year as follows :—

To Sir Paul Fildes, O.B.E., F.R.S., for his classical researches on growth factors for bacteria and for laying the foundation of work leading to a rational approach to chemotherapy.

To Professor N. F. Mott, F.R.S., for his eminent work in the field of quantum theory and particularly in the theory of metals.

Other medal awards have been made by the President and Council of the Royal Society as follows :—

The Copley Medal to Professor A. J. Kluyver, For.Mem.R.S., for his distinguished contributions of a fundamental character to the science of microbiology.

The Davy Medal to Sir John Lennard-Jones, K.B.E., F.R.S., for his distinguished work on the applications of quantum mechanics to the theory of valency and to the analysis of the intimate structure of chemical compounds.

The Hughes Medal to Sir Edward Bullard, F.R.S., for his important contributions to the development, both theoretical and experimental, of the physics of the earth.

American Iron and Steel Institute Medal

Mr. W. C. Bell, of Stewarts and Lloyds, Ltd., has been awarded the American Iron and Steel Institute Medal for 1953, for a paper entitled "A Review of European Operating and Technical Practices" which he delivered in New York on May 27th, 1953. This medal, which is awarded annually for a paper of special merit and importance to the American iron and steel industry, was established in 1927 and has a two-fold purpose: to perpetuate the memory of Elbert H. Gary, the first President of the Institute, and to stimulate improvements in the American iron and steel industry. There are no restrictions regarding the nationality of the recipient, but this is the first occasion on which the medal has been given to anyone other than a citizen of the United States.

Mr. Bell attended Allen Glen's School and the Royal Technical College, Glasgow. He joined the laboratory staff of the Clydesdale Steel Works of Stewarts and Lloyds, Limited, after serving in World War I. In

1924, he become assistant manager, open hearth plant, at the Clydesdale Works. Six years later he went to the Bilston Iron and Steel Works as works metallurgist. In 1936, Mr. Bell became assistant general manager of the Bilston Works and went to the Corby Iron and Steel Works, Mines and Quarries, as general manager in 1939. He is now a local director of the Company and joint director in charge of research and technical development, including planning and new construction of iron and steel works throughout the Company.

New British Chemical Standards

Bureau of Analysed Samples, Ltd., who have now removed to Newham Hall, Middlesbrough, announce four new standard samples, each of which has been analysed by eight or more metallurgical analysts representing manufacturers, users, and appropriate Government Departments. The standardised analyses are as follows :

Magnesium Aluminium alloys	B.C.S. No. 262 (D.T.D. 300) %	B.C.S. No. 263 (D.T.D. 165) %
Copper	0·03	0·13
Magnesium	10·57	4·23
Silicon	0·10	0·14
Iron	0·18	0·41
Manganese	0·06	0·50
Zinc	0·05	0·05
Chromium	0·06	0·34
Titanium	0·10	0·05

Low Carbon Steels	B.C.S. No. 264 %	B.C.S. No. 265 %
Carbon	0·037	0·047
Manganese	0·36–	0·44–
Nitrogen	0·013	0·020

These low carbon steels together with B.C.S. No. 230 form a new series of steels standardized for nitrogen.

The Bureau also announces a replacement of a low carbon Ferro-Chromium No. 203/1, and the standardisation of B.C.S. No. 163 for phosphorus (0·049%) to provide a figure close to the specification limit of 0·05%.

Supplies of these standards may be obtained direct from the Bureau or through any well-known laboratory furnisher.

Machine Tool Agency

An agreement has recently been concluded whereby Wickman, Ltd., become the sole selling agents of the well-known Swiss machine tool manufacturers, Edouard Dubrid et Cie., of Neuchatel. The manufacturing programme at present comprises : rapid copying lathes ($4\frac{3}{4}$ in. centre height, $15\frac{3}{4}$ in. and $25\frac{5}{8}$ in. between centres); high production lathes of similar capacities, and universal tool and cutter grinding machines.

Royal Society of Arts
Bicentenary Competition

The Royal Society of Arts will reach its bicentenary in March, 1954, and with this in mind its Council is arranging, in addition to various customary forms of celebration which will commemorate the Society's past achievements, a competition which will focus attention upon the future. The Society accordingly offers Prizes totalling £500, the largest being £250, for conceptions of life on this planet in the year 2,000 A.D., and forecasts (in visual or written form) are invited of the future developments which may be looked for in some particular aspect of life related to Arts, Manufactures and Commerce, the field of the Society as defined in its full and original title. For example, a competitor might give his ideas of what transport, housing, food or clothing may be like in 2,000. The chief criterion in assessing the entries will be originality. Full terms and conditions relating to the competition, together with registration forms, may be obtained from the Secretary, Royal Society of Arts, John Adam Street, W.C.2. Registration forms must be competed and returned together with an entry fee of 1s. by February 15th, 1954, and the actual competitive material submitted by June, 30th, 1954.

Personal News

The Wellman Smith Owen Engineering Corporation, Ltd., announces that Mr. F. H. Brooks has been appointed Technical Director of the Company, and that Mr. C. Brooks succeeds him as General Works Manager.

Additions have been made to the Board of Fletcher Miller, Ltd., Hyde, Cheshire, manufacturers of industrial lubricants, by the election of two new directors. These changes were occasioned by the death of Mr. J. F. Miller, late Chairman of the Company. The reconstituted Board consists of Mr. S. R. Miller, Chairman ; Mr. R. T. Miller, Director ; Mrs. M. Agate, Director ; and Mr. A. George, F.C.I.S., Director and Secretary.

The United Steel Companies, Ltd., announce that they have appointed Commander K. H. S. Cohen, C.M.G., as their European adviser. For some time the Company has wished to make a closer study of the trends in European industry and economics, and Commander Cohen is to undertake this work on their behalf. After a distinguished naval career, he was seconded to the Intelligence Department of the Foreign Office, where for a considerable number of years he was responsible for continental information.

The Directors of The Effingham Steel Works, Ltd., Sheffield, announce that their London Representative, Mr. R. Lloyd, is now a Local Director of the Company.

Mr. H. McNeil, Director and General Manager of Babcock & Wilcox, Ltd., has been appointed Deputy Managing Director. He is succeeded as General Manager by Mr. J. S. Robertson.

Mr. J. R. Kelly has joined the Board of Vickers-Armstrongs, Ltd., and has taken over the office of General Manager of the Crayford, Dartford and Whitehead Torpedo Works of the Company. Mr. Kelly has also joined the Boards of Power-Samas Accounting Machines, Ltd., G. J. Worssam & Son, Ltd., and A.B.C. Motors, Ltd.

Mr. H. G. Nelson has been appointed to the Board of the Canadian Marconi Company. Mr. Nelson is Deputy Managing Director of The English Electric Co., Ltd., and a Director of Marconi's Wireless Telegraph Co., Ltd., the English Electric Valve Co., Ltd., and a number of other companies. English Electric recently acquired controlling interest in the Canadian Marconi Company, and Mr. Nelson's appointment will assist in creating a close liaison between these two organisations.

The appointment is announced by Johnson & Phillips, Ltd., of Mr. E. F. Ward as the Company's Assistant Manager, Contracts Department.

To mark the completion of 25 years service with the Company, Mr. A. H. A. Barton, Production Manager in Charge of Planning and Stores of the Mullard Valve Co., Ltd., was presented with a cheque and a combined bureau and bookcase.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Internal Die Grinder

To their extensive range of die shop equipment Rudkin & Riley, Ltd., have added a new Internal Grinding Machine (type 2018/3), designed for a wide range of components, including tugsten carbide dies etc. The machine can be fitted with attachments for external grinding, and with a coolant supply where wet grinding is necessary.

The machine is fitted with automatic reciprocating traverse of the grinding carriage, giving an adjustable stroke of 4 in. maximum : the reciprocating mechanism is driven from a separately controlled $\frac{1}{2}$ h.p. motor and is easily and quickly adjusted for the required length of stroke. An alternative hand-operated arrangement is also fitted, with an adjustable stop to determine the forward stroke when the grinding carriage is operated manually. The air-cooled grinding spindle runs at 20,000 r.p.m. and can be supplied to take either grinding quills or grinding wheels, whilst the headstock will accommodate self-centring chucks (5 in. maximum) or collets where preferred. To ensure smooth traverse, the grinding carriage operates in a vee bed and ball bearings.

A well proportioned headstock which can be swivelled from 0° to 15° is fitted with a slide bar which carries a diamond tool for dressing the grinding wheel, and also a steady for grinding between centres. For wet grinding, a protective hood is fitted. The grinding spindle unit on the grinding carriage can be reversed, thus off-setting the grinding spindle $2\frac{1}{4}$ in. to allow for external grinding, in conjunction with a support for centred workpieces extending from the slide bar. For mass production a rapid lever clamping arrangement is fitted to the headstock.

A unique attachment which is also available is an arrangement for lapping and polishing parallel bores down to fine diameters and to the required size, at the same time ensuring a true parallel throughout and avoiding " bell-mouth." The setting of this arrangement before operation is determined electrically. By the application of a new type of lap, which has also been developed by the makers, ground bores can be lapped to a fine finish immediately after grinding by substituting a lap for the grinding wheel, and without removing the workpiece from the machine.

Rudkin & Riley, Ltd., Aylestone, Leicester.

Emulsion-Type Degreasant

Jenolite Ltd. have recently added a new preparation to their range of chemical degreasants. It is the Emulsion-type Degreaser, which may be used in the concentrated form supplied or in warm water dilutions up to 1 : 1 to meet individual requirements. Especially effective when applied by agitation with a stiff brush, it may also be applied by the standard immersion process. Non-inflammable, it is a suitable degreasant for all types of metal where no attack can be tolerated. A typical application is on aircraft components or on the underside of motor vehicles, where, in addition to grease, the usual layers of dirt and caked mud are efficiently and speedily removed by the subsequent water rinse, leaving a spotless metal surface.

Jenolite, Ltd., 43, Piazza Chambers, Covent Garden, London, W.C.2.

X-Ray Processing Units

The Kodak X-ray Processing Unit Model 112 and Kodak X-ray Washer Model 112 are designed for radiographic departments faced with the task of developing, fixing and washing large numbers of radiographs in the shortest possible time. Together, the processing unit and washer form a compact and simple assembly in which, under controlled conditions, X-ray films up to 14 in. × 17 in. can be processed and washed at a rate of between 90 and 100 per hour. In both units all the controls are mounted in a recessed control panel at the front, and all the pipe fittings, including the water supply and waste, are located in front behind a detachable panel. This innovation ensures convenience in operating and ease in servicing.

The processing unit acts, in effect, as a thermostatically controlled water jacket, holding approximately 55 gallons, heated by a 600-watt Aidas immersion heater. A Cambridge dial thermometer, in conjunction with a Sunvic hot-wire relay, controls the heater and thus regulates the temperature of the water. A safety device ensures that the heater is automatically cut out if the water falls below a safe level.

The unit contains one 10-gallon developing tank, a rinse compartment and two 10-gallon fixing tanks. The developing tank, which can take up to 12 films in hangers, has a light-tight lid, which allows the user to work for short periods with overhead lights. At the top of the built-in rinse compartment are two spray tubes which thoroughly and quickly rinse the films on both sides. If preferred, a running rinse can be provided in place of the spray tubes.

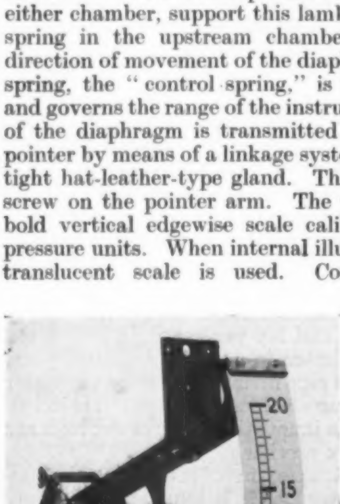
The self-contained washer is similar in design to the processer and either can be obtained as a separate unit. The washer has two compartments: each holds 30 gallons of water and each can accommodate 24 film hangers up to 14 in. × 17 in. Fixtures are provided in each compartment to hold a tank for a solution of wetting agent. Both washing compartments operate independently and the flow of water is controlled by separate valves. When only one compartment is required for washing the films, the other may be used to drain them before they are washed.

Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Differential Draught Gauge

A recent development in the range of instruments manufactured by George Kent, Ltd. for assisting combustion control is the Differential Draught Gauge. Of the many instruments used in the measurement of differential pressure it is the simplest, and therefore exceptionally useful on all boiler plants down to the smallest. The gauge is especially useful on those boilers fired with pulverised fuel, the load on the pulverising mill being indicated by the differential pressure across the mill. There are similar applications for the gauge on sinter plants, etc.

The measuring element is a sturdy diaphragm-operated mechanism. The diaphragm divides two pressure-tight chambers, one receiving the upstream pressure and the other the downstream pressure. Two springs, one in either chamber, support this lambskin diaphragm. The spring in the upstream chamber ensures the correct direction of movement of the diaphragm; and the other spring, the "control spring," is of calibrated strength and governs the range of the instrument. The movement of the diaphragm is transmitted to the light balanced pointer by means of a linkage system through a pressure-tight hat-leather-type gland. There is a zero-adjusting screw on the pointer arm. The pointer indicates on a bold vertical edgewise scale calibrated in differential-pressure units. When internal illumination is required a translucent scale is used. Consistent operation is ensured by the generous dimensions of the diaphragm, and an accuracy of ± 2% of maximum differential head is guaranteed. The instrument is capable of measuring up to 30 in. w.g. differential head. A dust- and fume-proof case houses the differential unit. Ranges available are 0–2, 0–3, 0–4, 0–6, 0–9, 0–12, 0–16, 0–20, 0–25, 0–30 in. differential pressure.



George Kent, Ltd., Luton.

Insulating Covers for Bale-Out Furnaces

Many attempts have been made in the past to try and alleviate one of the principal burdens of the die-casting furnace operator—the heat radiation from the molten metal bath—for despite the many improvements that have been made to other items of foundry equipment, inevitably the operator has had to "bale-out" by hand the metal from a furnace, and suffer from the heat given off from the surface of the molten metal. This heat radiation and its effects on workmen has been no small problem, but The Morgan Crucible Co., Ltd., have developed a new segmental insulating cover that virtually ends this difficulty. This is called "The Morgan Float," a product for which patent rights have been sought.

Morgan Floats are sold in sets of four segments, each segment being made from M.I.22 Insulating Concrete. This insulating concrete is a product of the Company's Refractory Group at Neston, Wirral, Cheshire, and is treated with a "Salamander" Plumbago Coating to act as a protection against wetting by molten aluminium. The four sections float on the surface of the molten metal (as shown in the illustration) and, by preventing heat radiation, result in a substantial saving in fuel, which may amount to 15%, and a considerable improvement in working conditions. Furthermore, as the cover is in intimate contact with the molten metal it reduces the disturbance of the surface and prevents continual oxidation.

The presence of the Floats does not impede casting in any way: when the ladle is dipped in the metal, the segments are easily displaced, but immediately the ladle is removed the segments float back again into position.

At present Morgan Floats are being made in one size only, this size being suitable for the 200, 300 and 400 lb. aluminium capacity sizes of bale-out furnaces.

The Morgan Crucible Co., Ltd., Battersea Church Rd., London, S.W.11.

CURRENT LITERATURE

Book Reviews

INDUSTRIAL INORGANIC ANALYSIS

By Roland S. Young. 368 pp., including author and subject indexes. London, 1953, Chapman & Hall, Ltd. 36s. net.

For a volume of this size and price we find a wealth of analytical information which is not only directive but also instructive. The author in his preface points out, very rightly, that so many of the well-known analytical textbooks fall short, all too often, in two respects. Firstly, in the comparatively few elements dealt with, and, secondly, and much more important, in the vague manner in which chemical principles are given for the methods quoted.

This book has tried to present the bulk of the elements likely to be encountered in metallurgical analysis in such a fashion that the reader gains a good idea of the most suitable or recommended procedure for the material concerned, and is also given some details of the chemical principles involved in the technique outlined.

Under the heading of "General Procedure" for each element, the author presents his principles, snags, interferences, etc., and then proceeds to give directions for "Specific Estimations" of the elements in certain industrial materials in which the element is commonly presented for analysis. In many cases these "Special Procedures" are very brief, and often mainly references to standard analytical textbooks or published papers, but they are undoubtedly well chosen, showing many years experience of the subject.

The book is written not only for the industrial analytical chemist, but also for the advanced metallurgical or chemical student doing a university degree course. These students may well find that the information given, although useful, is insufficient for their needs, in which case they, in company with the works analyst, must resort to the references for further specific information, for one cannot expect everything in a book of this size whose value and usefulness far outweigh its shortcomings.

It is refreshing to see some departure from the "cookery book" practice of so many analytical textbooks, and here we have a volume written by a chemist of some repute with the object in view of giving the reader some measure of information on "why" he is carrying out a certain set of operations as well as "how." This is all too important, but so often overlooked, when recommending a book for the use of advanced students.

In some 320 pages, recommended procedures are given for the estimation of over 40 elements, which in itself must necessitate a discourse which, despite its briefness in some cases, is in the main ably presented. The final chapter deals with certain miscellaneous items, such as analyses of gases, water, xanthates, the preparation of standard acids and bases and the choice of indicators.

Each element carries a comprehensive list of references for further information on particular aspects of the methods given in the text. These references are suitably placed at the end of the section dealing with the specific element. A list of some 70 reference books on metallurgical analysis and a further 10 pages of well-chosen index for both authors and subjects completes this volume.

V.S.K.

HISTORY OF STRENGTH OF MATERIALS

By S. P. Timoshenko. 452 pp., including name and subject indexes and numerous illustrations. New York, Toronto and London, 1953. McGraw-Hill Book Co., Inc. 71s. 6d.

A new Timoshenko book is always an event in the engineering world. This book is no exception, although for the first time we meet Timoshenko as an historian instead of a teacher of Strength of Materials. After a brief introduction in which are mentioned the building works of the Greeks and the discoveries of Leonardo da Vinci, the history commences with the work of Galileo in the seventeenth century and proceeds in roughly chronological order up to the present day. It is very noticeable that the greater part of the book deals with the work done in the nineteenth century, during which period most of the strength of materials which we now use was initiated.

A history of this kind should be of great assistance to the student to whom the subject of Strength of Materials might otherwise appear to be a series of clever mathematical manipulations, since the book as a whole shows how the present knowledge of the subject has accumulated from the work done to satisfy the demands of engineers as new developments in mechanical and civil engineering have arisen. It is interesting to note how much of the information which is still our basis for design was already known 100 years ago.

In this book, many names which are familiar by association with formulae and principles, acquire human relationships. Young, of the Modulus, appears as a precocious boy, a talented man, and a poor teacher. Eular, whose name is always connected with the well-known strut formula, is revealed as a brilliant man who, when almost blind, produced over 400 papers during the last 17 years of his life. A notable omission from the section dealing with progress during recent years is the name of Timoshenko. Presumably we must wait for a history by another author before we can have an account of the part which he has played in the advancement of Strength of Materials.

R.G.H.

Trade Publications

In order to make available, as rapidly as possible, figures determined since the last edition of their data book on The Nimonic Alloys, Henry Wiggin & Co., Ltd. have issued a supplementary leaflet containing additional and amended tables. Torsion properties of Nimonic 80A and Nimonic 90 have now been determined over the range 20–1,000° C. and more complete fatigue figures are also available. Short-time creep tests on Nimonic 95, the latest alloy in the series, are included, and new tables summarise recommended heat-treatments, and acceptance creep tests. Copies are available from the Company at Wiggin Street, Birmingham, 16.

The technical suitability of aluminium alloys for marine work is by now an established fact. There is ample evidence in existence covering the past twenty years to show that it is practical to reduce the weight of many ships' structures to less than half their weight in steel by using light alloys. "Ships Structures," a brochure

issued by The British Aluminium Co., Ltd., illustrates the extent to which aluminium alloys are already being used for deckhouses, wheelhouses, funnels and other relatively small superstructures, together with some examples of larger installations, and shows that further weight saving can be effected by more extensive use of these alloys in larger vessels. A further British Aluminium publication, "Aluminium Sections for Marine Uses," gives dimensional details of the bars, sections and tubing available for constructional purposes.

FOUR new leaflets have just been prepared by Deloro Stellite, Ltd., Highlands Road, Shirley, Birmingham. Two of them describe new welding rods, Delchrome and Alloy 'C.' The former is a hardfacing rod supplied for oxy-acetylene or arc welding. It is designed for resistance to abrasion only, being cheaper than Stellite which resists abrasion, heat and corrosion. Alloy 'C' is a nickel-molybdenum-chromium alloy manufactured in the form of plain and coated welding rods for depositing purposes, and as sand and investment castings. This material is resistant to heat and corrosion. Of the remaining leaflets, one deals with precision castings in Stellite and the other one with the use of Stellite alloys in the forging industry where they find application in drop forging hammer dies; press forging die inserts and upsetting and piercing punches; cropping blades; and hot chipping beds and punches.

A BROCHURE has been prepared by High Duty Alloys, Ltd., Slough, Bucks., for the guidance of manufacturers who have a standard machine shop and who intend to machine aluminium and magnesium alloys together with various other ferrous and non-ferrous materials. In the case of aircraft factories and other places where aluminium alloys form the bulk of the material to be machined, special purpose machines are available and greater speeds and feeds can be obtained; consequently, different rules apply to the design of the tools.

WE have received from Funditor, Ltd., 3, Woodbridge Street, London, E.C.1., their latest Marking Machine Manual. Throughout the ages, an identifying symbol or trade mark has denoted pride of craftsmanship and has become an identifying guarantee to the user. The application of such markings to components is one of the purposes of the equipment illustrated in the booklet. There are of course other purposes such as the marking of part numbers in mass production operations and the marking of serial numbers, names, graduations, instructions, etc.

ILFORD, LTD., have recently issued a leaflet describing the properties and uses of Phenidone. This is a new developing agent which was discovered in the Ilford Laboratories in 1940. After the war a process for the large-scale economical manufacture of Phenidone was devised, and it is now replacing metol in many old-established Ilford pack developers, and is also being used in several entirely new formulae designed to make the best use of its many excellent properties. In addition, supplies of Phenidone are now available for those who prefer to compound their own developers. This agent has many advantages over metol, further details of which are given in the leaflet, together with instructions for its use.

As part of the extension programme of Canadian Tube and Steel Products, Ltd., Montreal, The Incandescent Heat Co., Ltd., obtained contracts for two treatment lines. These were a continuous strand patenting, cleaning and coating line, capable of handling simultaneously high carbon steel rods, from the rolling mill, and drawn wire; and a continuous annealing, cleaning and galvanising line for wire. A description of the plant appeared in "Wire Industry," and reprints of this article, with the title "Incandescent in Canada," are available from the Company.

CARBON and graphite, with their wide variety of properties both thermal, chemical and physical, have long been of interest to the chemical and process engineer as a material for the construction of plant handling corrosive fluids. In their untreated form, these materials suffered from certain inherent limitations which restricted their use. The Morgan Crucible, Co. Ltd., with their background knowledge of the treatment of carbon and graphite and its use in a large number of industrial applications, together with their extensive research facilities, developed Carbinert (impervious carbon and graphite) as the answer to the engineer's demands. Further details of this material and its applications to heat exchangers, chemical plant, etc., are to be found in the pamphlet recently issued by the Company.

THE story of the development and production of the well-known Nimonic Alloys is told in an illustrated publication entitled "Nimonic Alloys in Aircraft Production," issued by Henry Wiggin & Co., Ltd. A gas flow diagram of the Rolls-Royce Derwent 5 Turbo-jet is shown as typical of the application of these high-temperature alloys for such components as combustion chamber linings, stator and rotor blades. Properties of the Nimonic alloys are summarised and a brief indication given of the uses of the various grades. Copies of this publication are available on request from the Company at, Wiggin Street, Birmingham, 16.

Books Received

"Elements of Heat Treatment." By George M. Enos and William E. Fontaine. 286 pp. inc. numerous illustrations. New York and London, 1953. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 40s. net.

"Fabricated Materials and Parts." By Theodore C. Dumond. 332 pp. inc. numerous illustrations. New York and London, 1953. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 52s. net.

"A Handbook on Die Castings for the use of Service Designers and Inspectors." Compiled by F. D. Penny, B.Sc.(Eng.) in collaboration with members of the Advisory Committee (Die Casting), Ministry of Supply. 78 pp. London, 1953. Her Majesty's Stationery Office. 6s. net.

"Heat-Resisting Steels and Alloys." (A concise Data Book giving the high-temperature properties of commercial steels and alloys.) By C. G. Conway, B.Sc. 160 pp. London, 1953. George Newnes, Ltd. 25s. net.

"Engineering Steels." (A Study of the Properties of Steels and the Principles Governing their Selection for Engineering Applications). By Leslie Aitchison, D.Met., M.Sc., F.R.I.C., F.R.Ae.S., M.I.Mech.E., F.I.M., and William I. Pumphrey, M.Sc., Ph.D. 923 pp., including numerous illustrations. London, 1953. Macdonald & Evans, Ltd. 105s.

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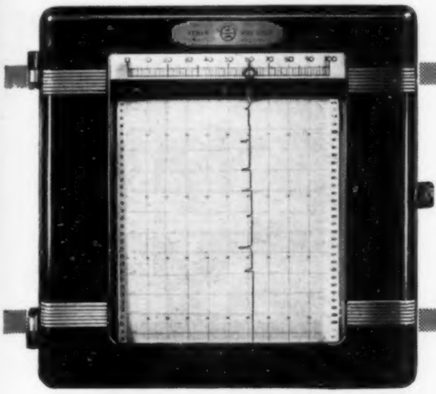

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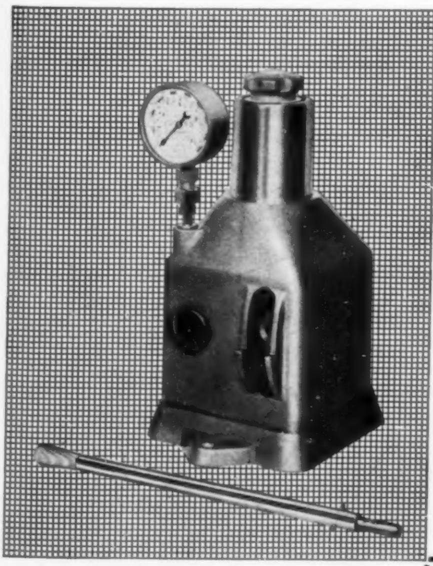

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DECEMBER, 1953 Vol. XLVIII, No. 290

The Electrolytic Deposition of Iron as an Analytical Technique

By J. O. Lay, F.R.I.C.

The British Iron and Steel Research Association

Procedures for the electrolytic deposition of iron have been examined and the effect of interfering elements has been assessed. While it has not been possible to devise a comprehensive method for analytical work, a technique is recommended which can be employed on a wide variety of materials and confirmatory results are reported.

THE determination of copper, zinc, cadmium, nickel, cobalt and other metals has been carried out on a quantitative basis by electrolytic deposition for several years, and there seems no obvious reason why iron should not be similarly determined. A survey of the literature shows that iron has been deposited electrically under various conditions, but no attempt appears to have been made to define a method of quantitative extraction from a solution containing other metals. Such a method might prove of particular value in view of the recent conclusions[1] reached by the Methods of Analysis Committee of the British Iron and Steel Research Association on the limitations of the well-known stannous chloride procedure in the volumetric determination of iron, and could be especially applicable in those cases where elements invalidating the aforesaid procedure are present.

The use of electrodeposition as an analytical procedure was applied to the determination of iron as early as 1879, and dealt with in fair detail by Classen in 1881.[2] His technique of using an oxalate solution was employed with minor modifications by many subsequent workers, notably by Smith[3] and Neumann.[4] The former, however, also mentioned alternative media of somewhat less satisfactory, although adequate, behaviour, and the latter gave a survey of procedures available at that time, while still recommending deposition from an iron ammonium oxalate solution as being most reliable. A more recent statement of the position by Sand[5] discloses no new advances in technique, and it may, therefore, be considered that the position is relatively unchanged.

Most of the earlier authors refer briefly to the possibility of interference by co-deposition of other elements present in solution, basing their experimental work and recommendations largely on pure solutions. The elements most particularly mentioned are manganese, nickel, cobalt and cadmium, but it is evident, from a consideration of the cathode potential curves and temperature effects,[6] that correct adjustment of conditions is necessary to prevent metallic radicals other than those specifically mentioned from being co-deposited with the iron.

Another possible source of error is the separation of carbon into the iron deposit during electrolysis, but Classen's investigations, supported by later workers, appear to show that such errors only arise if electrolysis is unduly prolonged.

Industrial Applications

Little reference appears to have been made to the commercial electrodeposition of iron since 1939, although before that date several industrial processes for the preparation of pure iron, often with the use of insoluble anodes, were patented.[7, 8, 9] Most of these, however, claimed no more than 50% recovery. In the majority of cases, purity of the deposit is ensured by the absence of elements likely to be co-deposited,[10, 11] and more recently published information[12, 13, 14] deals with the production of high-purity iron powder by this method. Electrolytes recommended in these articles can be roughly classified under the following heads :—

(*i*) ferrous chloride with calcium, manganese and other additions ;

(*ii*) ferrous sulphate, generally in conjunction with ammonium sulphate ; and

(*iii*) alkaline suspensions.

Precise details of the operation of industrial plating baths are available,[15] including the use of addition agents, but no indication of possible recovery is quoted.

Experimental

The first step in an investigation of this nature is obviously to confirm the work of previous investigators,

1 Methods of Analysis Committee, *J.I.S.I.*, Aug. 1952, **171**, 4, 392–403.
2 Classen, A. (W. T. Hall, trans.) "Quantitative Analysis by Electrolysis," Chapman & Hall, London, 1913 (5th Edition).
3 Smith, E. F., "Electro-Analysis," Paul, Trench, Trubner & Co., London, 1908, (4th Edition).
4 Neumann, B. (J. B. C. Kershaw, trans.) "Electrolytic Methods of Analysis." Whittaker, London, 1898.
5 Sand, H. J. S., "Electrochemistry and Electrochemical Analysis," Vol. II Blackie & Sons, London, 1939.
6 Field, S., "Principles of Electrodeposition." Longman & Green, London, 1911,
7 *Engineering*, March 23, 1928, **125**, 339–40.
8 Amer. Electrochem. Soc., May, 1930, Preprints 17 and 25.
9 *Korrosion und Metallschutz*, Nov/Dec., 1939, **15**, 380–7.
10 *Metals and Alloys*, April, 1935, **6**, 97–99.
11 *Metal Industry*, July 2, 1937.
12 *Metal Progress*, Aug., 1946, **50**, 279–82.
13 I.S.I. Special Report No. 38, 1947, 3–7.
14 *Metal Treatment*, 1950, **XVII**, 62, 121–5.
15 Field, S. and Weill, A. D. "Electroplating."

TABLE I.—NOMINAL COMPOSITION OF BLAST FURNACE SLAGS AND RESULTS FOR IRON BY ELECTROLYSIS

Slag	Total Fe*	SiO_2	Al_2O_3	TiO_2	Cr_2O_3	MnO	CaO	MgO	V_2O_5	P_2O_5	F	Fe by electrolysis
MGS./100	7·35	9·2	0·8	0·2	0·4	5·9	51·6	5·8	1·1	11·1	1·8	7·3 7·4 %
MGS./101	11·5	8·1	1·3	0·5	0·4	3·4	48·4	6·0	1·0	14·0	—	11·4 11·55 %

* See reference 1.

and with this object a series of tests was carried out based on the details given by Classen. Solutions containing 0·25 g. of ferrous ammonium sulphate (0·0357 g. of iron) were prepared, and varying oxalate additions and current densities were employed for deposition of the iron on a fixed platinum gauze cathode, the anode being a rotating platinum spiral.

The basic composition of the solution (Solution I) was :—

Ferrous Ammonium Sulphate	0·25 g.
Sulphuric Acid (sp. gr. 1·84)	1 ml.
Water	approx. 100 ml.

To this, varying amounts of ammonium oxalate were added, while in each experiment 0·5 g. of oxalic acid was added initially and a further 0·5 g. after each 15 minutes electrolysis—this was to prevent the formation of CO_3 which is reputed to cause contamination of the deposit by carbon.

The results obtained indicated that in the presence of 5 g. of ammonium oxalate a current of 6 amp. sufficed to deposit the whole of the iron in 30 minutes.

Several alternative procedures were investigated, e.g. the addition of ammonium sulphamate, ammonium fluoride, ammonium borate or sodium borate, and electrolysis of a chloride solution with carbon anodes, but no useful information was derived. The interference of other elements was then examined, when it was found that, although addition of ammonium persulphate prevented manganese deposition, nickel and cobalt were co-deposited with the iron, while to achieve deposition of all the iron under the suggested conditions the total metal content of the solution had to be kept below about 0·05 g. No significant difference in the character of the deposit was observed by variation of pH between 4 and 9, deposition generally taking place over the range pH 8·4–8·8.

Application of Tentative Procedure

Although success in the separation of various metals had not been obtained, it was felt that the alternative lines of investigation presented at this stage (e.g. variation of current density and cathode potential, examination of other complexing reagents, chemical separation of interfering elements) would increase the amount of research work undertaken beyond that justified by the immediate objective. A tentative analytical procedure was therefore drawn up and applied to two samples of blast furnace slag with the results given in Table I.

The method employed was as follows :—

0·2 g. of slag (*Note* 1) was moistened with water and decomposed with 5 ml. of hydrochloric acid (sp. gr. 1·16) and a few drops of nitric acid (sp. gr. 1·42). 20 ml. of sulphuric acid (1 : 3) was added, the solution evaporated and then taken to fumes by agitation over a free flame. The extract was cooled, the sides of the beaker washed down and the solution re-fumed as before. The extract was diluted to 25 ml., the solution boiled, 100ml. of ammonium oxalate solution (5%) added and the solution evaporated gently to about 75 ml. After cooling to about 50° C., the solution was filtered through a close texture paper (or pad) and washed to obtain a final volume of about 120 ml. (*Note* 2). 5 ml. of oxalic acid solution (10%) was added (with a further 5 ml. after 15 min.) and the electrolysis carried out with platinum gauze cathode and rotating spiral anode, for a period of 30 minutes, the voltage being 6 and the amperage 14.

Note 1. The amount of sample should be adjusted to give 0·01–0·04 g. of iron and the amount of hydrochloric acid varied accordingly. A little hydrofluoric acid may be added if required to assist decomposition ; if the undissolved residue is coloured it should be separated by filtration, decomposed and added to the solution before fuming. The sulphuric acid addition should be calculated to provide about 1 ml. of free sulphuric acid (sp. gr. 1·84), any excess being neutralised with ammonium hydroxide. The solution should be about pH 4 at the commencement of the electrolysis.

Note 2. In the presence of much manganese, add 2·5 g. ammonium persulphate, boil and cool the solution at this stage.

Conclusions

The complete deposition of iron from oxalate solution is practicable, but error is introduced by the presence of related elements. However, a method has been devised applicable to a wide range of materials from which these interfering elements are absent and the immediate objective of the research has therefore been achieved.

Acknowledgments

Thanks are due to Mrs. E. Drake (B.I.S.R.A.) for carrying out a considerable portion of the experimental work, to Dr. M. L. Becker (B.I.S.R.A.), Professor E. W. Yeoman (R.S.M.) and many others for advice and encouragement, and to the British Iron and Steel Research Association for permission to pursue and publish the results of the investigation.

Aluminium Watches for Long Service

On Thursday, November 12th, at Grosvenor House Hotel, Edgbaston, seven employees at Northern Aluminium Company's Works, Middlemore Road, Handsworth, were presented with aluminium watches in recognition of their 25 years' service to the Company. The presentations were made by the Managing Director, Mr. Fraser W. Bruce, and the recipients were Messrs Wilfred Adams (painter), Richard Davies (chargehand diecaster), R. James Hall (toolroom foreman), Sydney Law (die fitter), John Olbrechts (carpenter), Edward Parkes (grinder) and Leslie A Stokes (stamper). Also present were : Mr. C. P. Paton and Mr. B. N. H. Thornley, directors of the Company ; Mr. L. Fletcher, Works Manager (who was presented with an aluminium watch last year), and seven other employees who had already received similar long service awards. Among these guests were brothers John, William and Ivor Davies, who saw a fourth member of the family, their brother Richard, receive his aluminium watch.

A Note on the Preparation of Miniature Tensile Test Specimens

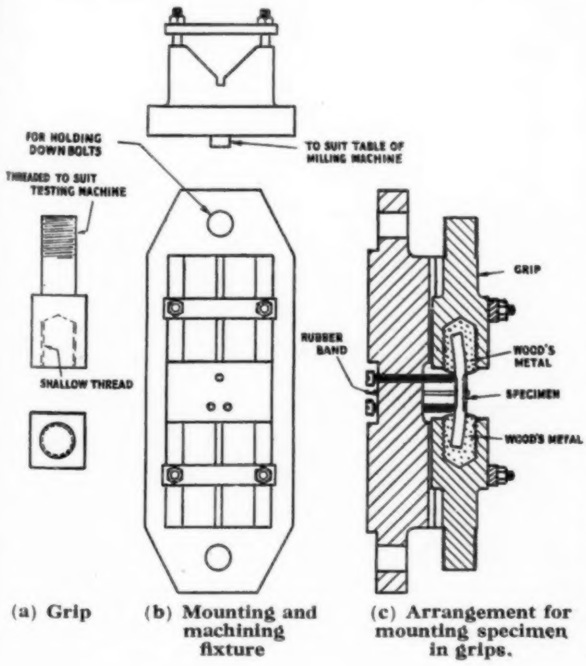
By R. J. M. Payne, B.Sc., F.I.M.

J. Stone & Co. (Charlton), Ltd.

Many occasions arise when it is desirable to carry out mechanical tests on diminutive test pieces cut from larger components in order to investigate the effect of segregates, etc., or to determine local properties. A method of preparing such test pieces is described.

A GREAT deal of useful information can be obtained by carrying out tensile tests on small specimens cut from different parts of semi-finished engineering components such as castings and forgings. The information so obtained is useful in several ways: it helps the manufacturer of the casting or forging in his efforts to improve his product, and it provides realistic guidance to the designer and user, thereby helping to ensure, particularly where a low weight is important, that effective use is made of the material. While a good deal of testing is carried out in this way for general guidance, there is, also, a call for tests when a close examination of the casting or forging discloses small-scale and perhaps highly localised metallurgical features, e.g., segregates of certain constituents of the alloy, the significance of which, in so far as mechanical properties are concerned, is not known.

In general, the carrying out of satisfactory tests of this nature is not easy, by reason of the complicated shaping of the parts concerned, and representative results are seldom obtained using ordinary methods of preparing test specimens. Screwed or shouldered round bars, particularly when taken from parts of thin section, usually have so small a cross-sectional area that they do not fairly represent the material tested. Flat specimens provide more useful information than do round ones, but are even more difficult to prepare unless the part of the component being studied happens to be flat. Objections to ordinary flat tensile specimens are that if pin grips are employed the heads of the bars need to be very big, and if serrated wedge grips are used it is difficult to secure truly axial loading. A simple way of overcoming these difficulties is described below.



(a) Grip (b) Mounting and machining fixture (c) Arrangement for mounting specimen in grips.

The equipment consists of a pair of special grips for holding the specimen, shown in the sketch at (*a*) together with a mounting and machining fixture (*b*). The grips are provided with a square head, and a tail which is threaded to fit into the testing machine shackles. Care is taken in machining the grips that the heads are truly square and parallel, and concentric with the screwed ends: a shallow thread is cut in the sockets. As shown at (*b*), the mounting fixture is nothing more than an accurately machined double-ended V-block. To prepare a specimen, the rough blank as sawn from the casting or forging is held against the three positioning screws by a rubber band and, by adjustment of the screws, positioned centrally with regard to the axis. One of the grips is now clamped to the V-block with the socket surrounding the end of the blank. The assembly is then held vertically and Wood's metal (fusible alloy) cast into the socket. On cooling, the other end is similarly treated (*c*).

The V-block, with the blank mounted in the two grips clamped thereon, is now taken to the milling machine, and the central test portion of the blank reduced to a rectangular or square section by end milling. The square ends of the grips permit this to be done easily. By turning the specimen through 180° and feeding in the cutting tool at the same setting, strict concentricity between the test portion of the specimen and the grips is ensured. As a consequence, the specimen is subjected to truly axial loading when finally set up in the testing machine, and reliable results should be obtained

Where a considerable amount of testing has to be done it is convenient to use separate fixtures for the mounting and machining operations. The method described proved particularly useful recently in evaluating the effects on strength of a segregate of the " healed-hot-tear " type in a light alloy casting; in this instance a representative test could hardly have been carried out by other means on account of the curvature of the casting and the thin section prevailing. The gauge length as machined was ½ in.

A Rapid Polarographic Method for the Analysis of Tungsten-Cobalt Alloys

By I. A. Bucklow, B.A., and T. P. Hoar, M.A., Ph.D., B.Sc., F.R.I.C., F.I.M.
Department of Metallurgy, University of Cambridge

A rapid method for the determination of tungsten and of cobalt in tungsten-cobalt alloys, involving dissolution in phosphoric acid and direct polarography of the unseparated metals, is described.

FOR systematic investigations of the electrodeposition of tungsten-cobalt alloys, a rapid method of analysis of moderate accuracy was required. Previous investigators in this field, for example, Brenner, Burkhead and Seegmiller,[1] analysed their deposits by the lengthy gravimetric determination of tungsten as the trioxide, and the determination of cobalt by various colorimetric methods. The present method requires no separation of metals ; each is determined polarographically with accuracy limited only by the polarograph.

The alloy, plated on platinum or stripped mechanically from a base such as stainless steel on which it is poorly adherent, is dissolved in 50% v/v aqueous phosphoric acid, and the solution is made up to a known volume with concentrated hydrochloric acid. In this solution tungsten (present as W^{6+} in the phosphotungstic acid complex) is directly determined by the method indicated by von Stackleberg, Klinger, Koch and Krath,[2] and by Lingane and Small.[3] An aliquot, freed from hydrochloric acid and concentrated by boiling, is diluted with distilled water ; cobalt is determined therein with the use of 1M ammonia–1M ammonium chloride as supporting electrolyte.[4]

Reagents Required

50% v/v aqueous phosphoric acid.
36% w/w aqueous hydrochloric acid (sp. gr. 1·18).
0·2% gelatin solution.
1M ammonia–1M ammonium chloride.

The following standard solutions, designed to be closely similar to the unknown solutions (see below), are also required :

Tungsten

0·5 g./l. W as sodium tungstate,
0·5 g./l. Co as cobalt sulphate,
10% v/v phosphoric acid,
made up with concentrated hydrochloric acid.

Cobalt

0·1 g./l. Co as cobalt sulphate,
0·1 g./l. W as sodium tungstate,
2% v/v phosphoric acid,
made up with distilled water.

Dissolution

Place *c.* 100 mg. of the alloy in a 100 ml. beaker, add 20 ml. of 50% v/v aqueous phosphoric acid, cover with a clock glass and boil. Dissolution is complete in about twenty minutes, although the higher tungsten alloys may take longer. Cool and make up to 100 ml. with concentrated hydrochloric acid (Solution 1).

Pipette 20 ml. of Solution I into a 100 ml. beaker ; boil until the bulk is small and most of the hydrochloric acid has been driven off. Cool and make up to 100 ml. with distilled water (Solution II).

Polarography

Tungsten

Pipette 10 ml. of Solution I into a 20 ml. volumetric flask, add 1 ml. of 0·2% gelatin solution (maximum suppressor) and make up with concentrated hydrochloric acid. This is the " Unknown " solution.

Pipette 5 ml. of Solution I and 5 ml. of standard tungsten solution into a 20 ml. volumetric flask, and complete as above. This is the " Reference " solution.

With a full-scale galanometer deflection corresponding to 10μA. at the dropping mercury electrode, and with suitable condenser-current and zero settings, take the polarograms between −0·10 and −0·50 V. (cell voltage) of the unknown and reference solutions. The tungsten half-wave potential occurs at about −0·42 V. (cell voltage). Sensitivity is of the order of 10μA./mg./ml.

Cobalt.

Pipette 10 ml. of Solution II into a 20 ml. volumetric flask, add 1 ml. of 0·2% gelatin solution and make up with 1M ammonia–1M ammonium chloride solution. This is the " Unknown " solution.

Pipette 5 ml. of Solution II and 5 ml. of standard cobalt solution into a 20 ml. volumetric flask and complete as above. This is the " Reference " solution.

With a full-scale deflection corresponding to 10μA. and suitable settings, take the polarograms between −1·00 and −1·40 V. (cell voltage) of the two solutions. The cobalt half-wave potential occurs at about −1·20 V. (cell voltage). Sensitivity is of the order of 100μA./mg./ml. It is not necessary to remove oxygen, although for the best accuracy it may be desirable.

Discussion

The limitations of accuracy of the method are imposed entirely by the polarograph and the interpretation of the polarograms. The instrument used in the present work was the Tinsley Model V3211 ; a consistent average accuracy of ± 2·5% for each determination can be achieved over a wide range of amounts and concentrations of the two metals. Table I gives some typical results, from which it may be seen that analyses of

1 A. Brenner, P. Burkhead and E. Seegmiller, *J. Res. Nat. Bureau Standards*, 1947, **39**, 351 ; " Proc. Third International Electrodeposition Conference" (Electrodepositors' Technical Society), 1947, p. 131.
2 M. von Stackleberg, P. Klinger, W. Koch and E. Krath, *Tech. Mitt. Krupp Forschungsber.*, 1939, **2**, 59.
3 J. J. Lingane and L. A. Small, *J. Amer. Chem. Soc.*, 1949, **71**, 973.
4 I. M. Kolthoff and J. J. Lingane, " Polarography " (van Nostrand), 2nd ed. 1952, p. 482.

TABLE I—TYPICAL RESULTS

Alloy Taken mg.	Tungsten Found mg.	Cobalt Found mg.	Total Found mg.
159·0	54·5	98·5	153·0
108·7	44·1	70·5	114·6
105·0	34·1	68·7	102·8
102·5	39·3	66·6	105·9
58·4	15·6	42·6	58·2
47·6	22·2	27·1	49·3
36·6	16·9	18·6	35·5
32·2	14·1	17·3	31·4
28·7	15·2	14·2	29·4
25·8	9·4	14·6	24·0
18·3	8·7	8·8	17·5
9·5	7·1	2·3	9·4

samples much less than the recommended 100 mg. are quite practicable.

Tungsten dissolves from the alloy to the hexavalent form in phosphoric acid solution, doubtless because of the stability of the phosphotungstic acid complex. Lingane and Small[3] showed that polarographic reductions of tungsten in several other valency states can be achieved in concentrated hydrochloric acid. It is thus satisfactory to note from Table I that determination of the dissolved tungsten on the assumption that is is entirely hexavalent, and so corresponds quantitatively to acidified sodium tungstate standards, is quite justified. Qualitative confirmation of the present procedure is found in the polarograms themselves: the tungsten half-wave potentials for solutions of the alloys, for standards prepared from sodium tungstate, and for mixtures of the two, are identical, and the polarograms are identical in form.

The presence of phosphoric acid prevents the precipitation of WO_3 during the manipulation of the solution for cobalt analysis, and has no detrimental influence upon the tungsten and cobalt waves; indeed, it tends to delay the discharge of hydrogen in the tungsten analysis and thus to render the top of the tungsten wave clearer.

Summary

Tungsten-cobalt alloys can be rapidly analysed by direct polarography of the solution formed by dissolving them in 50% v/v aqueous phosphoric acid. Concentrated hydrochloric acid is used as supporting electrolyte for the hexavalent tungsten, 1M ammonia–1M ammonium chloride for the bivalent cobalt.

Inconel Pots for Alkali Fusions

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IN the cleaning of diamond powder after crushing, and its reclamation from industrial wastes, it is frequently necessary to fuse substantial quantities with potassium or sodium hydroxide over a gas burner. Pots of cast iron and stainless steel which we have employed for this purpose have not been satisfactory. Cast iron pots are heavy and inclined to be brittle, while the presence of considerable quantities of iron derived from the vessel has required the subsequent treatment of the melt with hydrochloric acid. Stainless steel pots can be fabricated from much thinner material than is necessary with cast iron, and diamond powder fused in the former is much cleaner and requires less acid treatment. Stainless steel, however, did not give superior corrosion resistance to cast iron, vessels of 18–8 having a wall thickness of approximately $\frac{3}{32}$ in. being perforated in a period equivalent to about 18 hours continuous fusion.

In view of the well-known resistance of nickel, Monel and nickel-containing alloys to caustic soda, it was believed that these might be superior for such an application. At the suggestion of the Mond Nickel Co., Ltd., welded pots of Inconel 5 in. high, 6 in. diameter and $\frac{3}{32}$ in. thick were obtained for trial. The rate of corrosion was measured for a period of 24 hours by the quantity of nickel found in the fusion of a nickel-free synthetic mixture containing caustic alkali and the materials commonly found in the cleaning of diamond powder and in its recovery from industrial wastes. These included silica, silicon carbide, aluminium oxide, iron and other metals, tungsten carbide, graphite, dust and dirt, etc. Fifty grams of this mixture were added to 600 g. of caustic alkali. Fusion was carried out during eight hours on each of three successive days. At the end of each day the contents of the pots were emptied and a fresh fusion mixture employed the following day. The molten alkali occupied a height in the vessel of $1\frac{1}{4}$ in. for potassium hydroxide and $1\frac{1}{2}$ in. for sodium hydroxide, owing to the greater tendency of the latter to creep.

Under these conditions the corrosion rates were 193 and 189 mg./sq. dm./day, respectively, for sodium and potassium hydroxide fusions. Attack was quite uniform, as no pitting or etching of the surface could be observed after the test. This corrosion rate can be considered very satisfactory, assuring a long life of these pots with a minimum of contamination.

It has been recently reported that sub-surface voids may be found in Inconel during processes involving the depletion of chromium by high temperature oxidation, vacuum treatment, and leaching with certain molten alkali fluorides[1]. In our case, however, there was no preferential attack of the chromium by the caustic alkali fusion, and Inconel can be recommended for such an application.

1 de S. Brasunas, A. *Metal Progress*, **62** (6), 88–90 (1952).

C.P. London Plant Office Move

THE London Plant Branch Office of Crompton Parkinson, Ltd., has been moved from Crompton House, Aldwych, W.C.2., to 1–3 Brixton Road, London, S.W.9. (Tel: Reliance 7676 15 lines). The other departments of the Company located at Crompton House will remain there. The London Plant Branch (Manager, Mr. K. Younger), is responsible for the sales of generators, motors, transformers, switchgear, power cable, instruments, traction batteries, and ceiling fans. The Branch also negotiates contracts for complete electrical power installations in oil refineries, paper mills, cement works, and all other industrial plants, power stations, etc.

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